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J. Van Voorst Esq

GENERAL OUTLINE

OF THE

ORGANIZATION

OF

THE ANIMAL KINGDOM.

GENERAL OUTLINE
OF THE
ORGANIZATION
OF
THE ANIMAL KINGDOM,
AND
MANUAL OF COMPARATIVE ANATOMY.

BY THOMAS RYMER JONES, F.R.S.,

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ETC. ETC.

Third Edition,
ILLUSTRATED BY FOUR HUNDRED AND TWENTY-THREE ENGRAVINGS.

LONDON:
JOHN VAN VOORST, PATERNOSTER ROW.
M.DCCC.LXI.

1295

1353368

LONDON:
PRINTED BY TAYLOR AND FRANCIS,
RED LION COURT, FLEET STREET.

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RICHARD OWEN, ESQ., F.R.S.,

ETC. ETC. ETC.,

THE FOLLOWING PAGES ARE INSCRIBED

BY HIS SINCERE FRIEND,

THE AUTHOR.

PREFACE TO THE SECOND EDITION.

The object of the writer of the present work has been twofold: first, to lay before the Naturalist a complete view of the organization and physiological relations of every class of living beings; and secondly, to offer to the Anatomical Student a succinct account of the structure and development of the vital organs through all the modifications they present in the long series of the animal creation.

Such were the intentions of the Author, as announced at the commencement of his undertaking; and the reception the first edition received at the hands of the public has been such as to afford gratifying proof that his efforts to facilitate the progress of the cultivators of a science the importance of which is becoming every day more conspicuous have not been unsuccessful.

Since the publication of the preceding edition, however, great and important advances have been made in our knowledge: many and earnest have been the labourers in this enticing field, and proportionately encouraging have been the results. The indefatigable industry of Professor Owen, conspicuous in every department of our science, has, by his invaluable analysis of the vertebrate skeleton, not only re-modelled the nomenclature of the osteologist, but placed in the hands of the Geological Student a light wherewith to guide his steps amid the darkness of departed worlds. The improvements in our microscopes, and the zeal of our microscopists, have much advanced our knowledge of the Infusorial organisms. The researches of Van Beneden and Siebold relative to the embryogeny of parasitic worms open before us a new field of research; while the observations of Steenstrup, Dalyell, and Agassiz, on the "alternation of generations" among the Hydriform Polyps and Acalephæ, promise results of the utmost interest to the Naturalist.

The discoveries of Milne-Edwards have importantly increased our information concerning the organization of the Mollusca as well as of the Alcyonoid Polyps; and those of Müller, revealing the metamorphoses of the Echinodermata, add new lustre to a name already so distinguished in science.

To particularize our own countrymen and fellow-labourers whose names give value to the following pages would be an invidious task; suffice it to say that the Author has endeavoured, to the best of his ability, to keep pace with their diligence and onward progress, so as adequately to record and acknowledge their contributions to the general stock of scientific lore.

To Mr. Van Voorst, the liberal Publisher of the present volume, the Author cannot but offer his best thanks; the numerous and costly illustrations that adorn the work speak for themselves, while his endeavours to publish it at a price placing it within the reach of every student will, it is hoped, be extensively appreciated.

PREFACE TO THE THIRD EDITION.

The short interval which has elapsed since the preceding preface was written affords additional evidence of the increasing usefulness of this work. Encouraged by such success, the Author, in revising the present edition, has supplied sundry omissions, and added such new observations as the onward progress of anatomical science seemed to require. Important alterations in the arrangement of the Animal Series have likewise been introduced, among which may be pointed out the complete separation of the Protozoa from the Ciliated Infusoria, the introduction and redistribution of the class Helminthozoa, the transference of the classes Rotifera and Cirrhopoda into close proximity with the Crustacea, to which they are related in many particulars of their economy, and the establishment of the Polyzoa as legitimate members of the Molluscous division of Creation. As a general rule, however, the Author has been careful to avoid unnecessary changes in zoological classification, from a conviction that they are rather calculated to embarrass than to facilitate the progress of the student of Comparative Anatomy.

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A GENERAL OUTLINE

OF

THE ANIMAL KINGDOM.

CHAPTER I.

ON CLASSIFICATION.

(1.) From the earliest periods to the present time, the great desideratum in Zoology has been the establishment of some fundamental system of arrangement which, being universal in its application, should distribute the countless beings surrounding us into natural groups or divisions, such as might be subdivided into classes, orders, and genera, by obvious differences of structure in the tribes composing them, and thus enable the Zoologist at once to indicate the position which any unknown animal ought to occupy in the scale of existence, and its relations with other creatures.

(2.) Aristotle, the father of our science, was the first who attempted a scientific division of the animal world *. The outlines of his system were rude in proportion to the necessarily limited knowledge at his disposal, although his efforts were gigantic, and still excite our warmest admiration. This acute observer admitted but two great sections, in one or other of which all known beings were included,—the highest comprehending creatures possessed of blood (*i. e.* red blood), corresponding to the Vertebrata of modern authors; the lowest embracing animals which in his view were exsangueous, or provided with a colourless fluid instead of blood, and corresponding to the Invertebrata of more recent zoologists †.

(3.) Linnæus, like Aristotle, selected the circulatory system as the foundation of his arrangement*, dividing the animal creation into three great sections, characterized as follows:—

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* Historia Animalium.

† *Πρὸς δὲ τούτοις τὰ μὲν ἔναιμα τυγχάνει ὄντα, οἷον ἄνθρωπος καὶ ἵππος καὶ πάνθ' ὅσα ἢ ἄποδά ἐστι τέλεα ὄντα ἢ τετράποδα, τὰ δ' ἄναιμα, οἷον μέλιττα καὶ σφὴξ καὶ τῶν θαλαττίων σηπία καὶ κάραβος καὶ πάνθ' ὅσα πλείους πόδας ἔχει τεττάρων.*—Περὶ Ζῶα Ἱστόριον, Κεφ. Α.

I. Animals possessed of *warm* red blood, and provided with a heart containing four compartments, viz. two auricles and two ventricles. Such are the MAMMALIA and BIRDS.

II. Animals with *cold* red blood, their heart consisting of but one auricle and one ventricle, as he believed to be the case in REPTILES and FISHES.

III. Animals possessed of cold white sanies instead of blood, having a heart consisting of a single cavity, which he designates an auricle: under this head he includes INSECTS and all other invertebrate animals, to which latter he gives the general name of VERMES, Worms.

We shall not in this place comment upon the want of anatomical knowledge conspicuous in the above definitions, or the insufficient data afforded by them for the purposes of Zoology. The apparatus of circulation, being a system of secondary importance in the animal economy, was soon found to be too variable in its arrangement to warrant its being made the basis of zoological classification, and a more permanent criterion was eagerly sought after to supply its place.

(4.) Among the most earnest in this search was our distinguished countryman John Hunter, who, not satisfied with the results obtained from the adoption of any one system, seems to have tried all the more vital organs, tabulating the different groups of animals in accordance with the structure of their apparatus of digestion, of their hearts, of their organs of respiration, of their generative organs, and of their nervous system, balancing the relative importance of each, and sketching out with a master hand the outlines of that arrangement since adopted as the most natural and satisfactory †.

The result of the labours of this illustrious man cannot but be of deep interest to the zoological student, and accordingly an epitome of his ideas upon the present subject is here concisely given.

The apparatus of digestion appears to be among the least efficient for the purpose of a natural division; as the separation of animals into such as have a simple digestive cavity, receiving and expelling its contents by the same orifice, and such as have an aperture for the expulsion of the contents of the alimentary canal distinct from that by which food is taken into the stomach, is by no means of practical utility, although this circumstance, as we shall afterwards see, has been much insisted upon.

Hunter's arrangement of the animal kingdom in conformity with the structure of the heart was a great improvement upon that of Linnæus.

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* Systema Naturæ. Vindobonæ, 1767. 13th edition.

† Descriptive and Illustrated Catalogue of the Physiological Series of Comparative Anatomy contained in the Museum of the Royal College of Surgeons in London, vol. iii. part i. 1835.

founded upon the same basis. He arranges in this manner all animals in five groups.

I. Creatures whose hearts are divided into four cavities—*Mammalia* and *Birds*.

II. Those having a heart consisting of three cavities—*Reptiles* and *Amphibia**.

III. Animals possessing a heart with two cavities—*Fishes* and most *Mollusca*.

IV. Animals whose heart consists of a single cavity—*Articulated Animals*.

V. Creatures in which the functions both of stomach and heart are performed by the same organ, as in *Medusæ*.

We shall pass over Hunter's sketches of arrangements founded on the respiratory and reproductive organs, as offering little that is satisfactory; but the researches of this profound physiologist upon the employment of the nervous system for the purpose of zoological distribution did much to inaugurate a more natural method of classification, afterwards carried out with important results.

(5.) The appearance of the "Animal Kingdom distributed in accordance with its organization," of Cuvier, formed a new and important era in Zoology. In this we find all creatures arranged in four great divisions, VERTEBRATA, MOLLUSCA, ARTICULATA, and RADIATA. These divisions, with the exception of the first, are named from the external appearance of the creatures composing them; nevertheless the three first are defined by characters exclusively drawn from their internal organization, the arrangement of the nervous system being essentially the primary character of distinction, and have been found to be strictly natural; whilst the last division, characterized by the appellation of RADIATA, in the formation of which the structure of the nervous system has been allowed to give place in importance to other characters of secondary weight, obviously embraces creatures of very dissimilar and incongruous formation.

(6.) The VERTEBRATA are distinguished by the possession of an internal nervous centre or axis, composed of the brain and spinal cord, which is enclosed in an osseous or cartilaginous case, and placed in the median plane of the body, giving off symmetrical nerves, which are distributed to all parts of the system. This general definition indicates a large division of the animal world, which, by secondary characters drawn from the structure of their organs of respiration and circulation, is separable into mammals, birds, reptiles, amphibia, and fishes.

(7.) The MOLLUSCA have a nervous system constructed upon a very different type, and do not possess any vertebral column or articulated skeleton. The nervous centres consist of several detached masses placed in different parts of the body, without regularity of distribution or symmetrical arrangement; and the entire group is obviously natural, although Cuvier has ranged in it some creatures which, in the structure of their nervous system, differ essentially from those comprised in his own definition.

---

* For the important discovery that the heart of the Amphibia is divided into three cavities, instead of being composed of a single auricle and ventricle, we are indebted to Professor Owen (*vide* Zool. Trans. vol. i.).

(8.) The class of ARTICULATED ANIMALS is likewise well characterized by the nervous system, which, in all the members of it, is composed of a double series of ganglia or masses of neurine, arranged in two parallel lines along the abdominal surface of the body, united by communicating cords, and from which nerves are given off to the different segments of which the body consists.

(9.) The fourth division of Cuvier, namely that of ZOOPHYTES or RADIATED ANIMALS, is confessedly made up of the most heterogeneous materials, comprising creatures differing in too many important points to admit of their being associated in the same group; and the efforts of subsequent zoologists have been mainly directed to the establishment of something like order in this chaotic assemblage.

(10.) The evident relation which the perfection of the nervous system bears to that of animal structure, and the success of Cuvier in selecting this as the great point of distinction in the establishment of the higher divisions of the animal kingdom, necessarily led succeeding naturalists still to have recourse to this important part of the economy in making a further subdivision of the Radiata of Cuvier. In some of the radiated forms, indeed, nervous filaments are distinctly visible, and such are among the more perfectly organized of the group; these, therefore, have been classed by themselves, and designated by Professor Owen the NEMATONEUROSE* division of the animal world; while those which are apparently without the least trace of distinct nervous matter have been formed by Mr. Macleay into a group by themselves, to which he has given the denomination of ACRITA†.

(11.) There can be no doubt that the nervous matter must be regarded as the very essence or being of all creatures, with which their sensations, volition, and capability of action are inseparably connected; and such being the case, it is a legitimate inference that the capacities and powers of the several tribes are in immediate relation with the development and perfection of this supreme part of their organization, and their entire structure must be in accordance with that of the nervous apparatus which they possess. The nature of the limbs and external members, the existence or non-existence of certain senses, the capability of locomotion, and the means of procuring food must be in strict correspondence with the powers centered in the nervous masses of the body, or in that arrangement of nervous particles which represents or replaces them.

* *νῆμα*, a thread; *νεῦρον*, a nerve.

† *α* priv.: *κρίνω*, to discern.

(12.) Granting the accuracy of the above view, it is obvious that, if exactly acquainted with the structure and elaboration of the nervous apparatus in any animal, we might to a great extent predicate the most important points in its economy, and form a tolerably correct estimate of its powers and general conformation. But, unfortunately, such knowledge is not always at our disposal: in the lower forms of the animal world especially, we are far from being able to avail ourselves of such a guide; and it will probably be long ere our improved means of research permit us to apply to practice the views which Physiology would lead us to adopt. It is, however, by no means our intention in the present work to enter the arena of discussion relative to the juxtaposition or precedence in the scale of animal existence which ought to be assigned to any particular group as defined by modern zoologists. The classification employed in the following pages is simply adopted as being the most convenient for our present object; we shall therefore arrange our studies in accordance with the following sequence.

CHAPTER II.

PROTOZOA*.

(13.) Rhizopoda†.—On carefully examining the contents of a marine aquarium, or a glass vessel casually filled with sea-water, the microscopic observer will not unfrequently perceive, adherent to the sides, numerous beings which, from their minute size and transparency, have until a very recent period entirely escaped notice, although the part they are destined to play in the economy of this world is by no means unimportant. The body of one of these remarkable organisms (fig. 1, 1) consists of a minute spherical vesicle, something resembling a globular flask provided with a short narrow neck, filled with a fawn-coloured glutinous substance containing numerous minute granules, and apparently unprovided with any external appendages. On placing one of these creatures, however, in a glass of sea-water (its native element), it is found in the course of a few hours to have attached itself to the sides of the vessel by means of numerous long ramified filaments of hyaline transparency, which soon begin to reveal their office to be that of a locomotive apparatus, by whose aid the animal can transport itself from place to place, but with such extreme slowness that its movements are hardly perceptible. The locomotive filaments thus displayed are perceptible by the naked eye, their length being, when fully extended, four or five times the transverse diameter of the body; still they exhibit in their interior no appearance of organization, but resemble so many threads of molten glass. When protruded, each of these filaments, at first simple and of equable diameter through its entire length, soon begins to elongate itself in a very mysterious manner, moving in different directions, as though seeking some basis of support. As the elongation of the filament continues, apparently owing to a constant influx of new material into its substance, it is seen to give off here and there secondary branches, which, in turn dividing dichotomously, give to the whole structure the root-like appearance represented in the figure. The retraction of these singular organs is accomplished by a sort of inversion of the above process, each filament shrinking as it were into itself until it totally disappears. The most remarkable circumstance, however, observable in the economy of these creatures is, that the protruded filaments are able to coalesce and, as it were, to become fused together, forming a gelatinous network that spreads out in all directions (fig. 1. 2).

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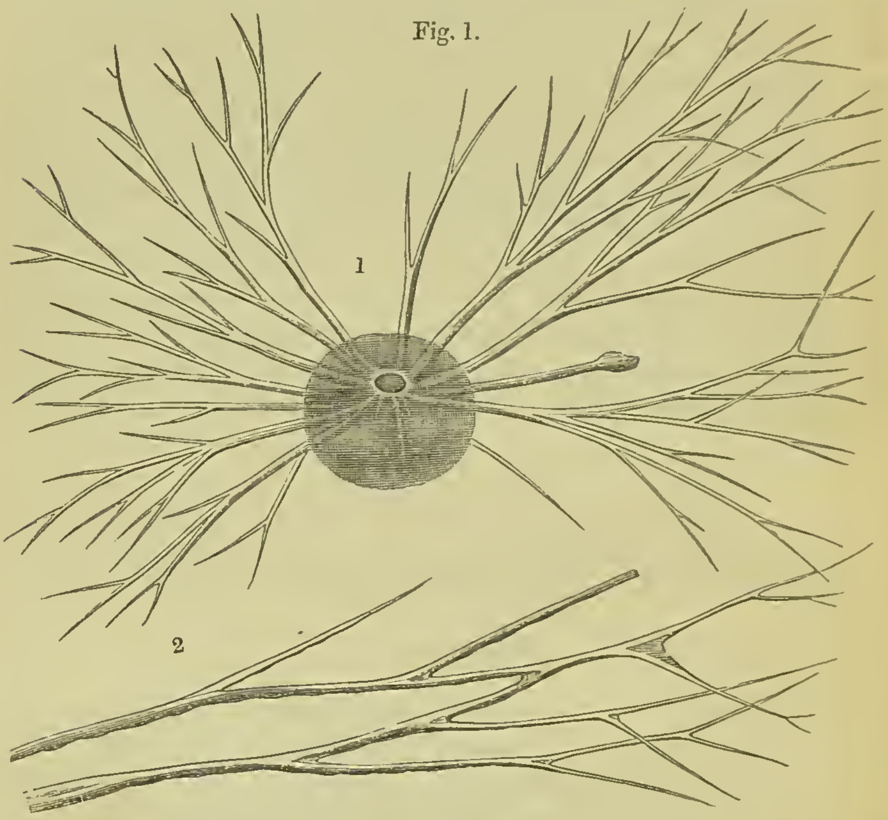
* πρῶτος, first; ζῶον, animal.

† *Vide* D'Orbigny, Dict. Univers. d'Hist. Nat. 1845, v., and Foraminifères Fossiles, 1846: Ehrenberg, Berlin Trans. 1838 and 1839, or Weaver's abstract, Ann. Nat. Hist. 1841, vii. pp. 296, 374: Dujardin, Ann. Sc. Nat. 1835, iv. & v.: Clark, Ann. Nat. Hist. 1849, iii. 380; 1850, v. 161: Williamson, Trans. Micr. Soc. ii. and Micr. Journal, i.: Carpenter, Trans. Geol. Soc. 1849, and Phil. Trans. 1856: Carter, Ann. Nat. Hist. 1852, x.

Fig. 1.



1. *Gromia oviformis*, with the rhiziform tentacles displayed.
2. Filaments fused together into a kind of network.

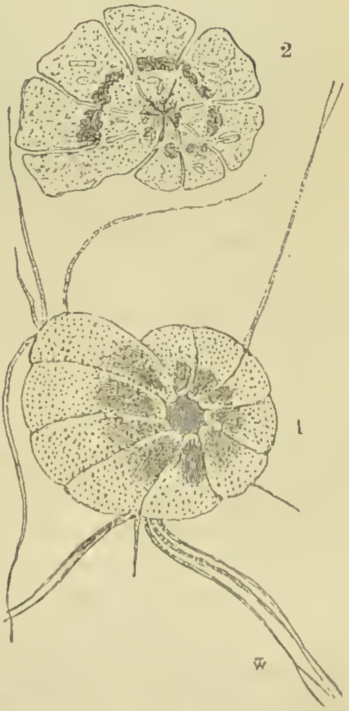
(14.) When a Rhizopod, having all its filaments thus extended, wishes to advance in any given direction, those threads which are directed in front become elongated, and those placed behind, on the contrary, are drawn forward, while the intermediate move so as to accommodate themselves to each change of position, thus evidently exhibiting a consentaneity of action.

(15.) Internally these creatures present no traces of any special nutritive apparatus; neither are there any organs appropriated to reproduction, their multiplication being apparently accomplished either by gemmation or by simple division, as any portion of the mass separated from the rest seems capable of living and of forming a new centre of organization.

(16.) The delicate body of *Gromia*, above described, is unprovided with anything like a shell; but there are many races presenting an organization in every way analogous (such as the *Miliolæ*, the *Cristellariæ*, the *Vorticialæ*, and others), that possess the power of secreting shells of very exquisite texture, many of which form extremely beautiful objects when examined under the microscope.

(17.) The Foraminifera constitute a very curious and remarkable group, important from the immense numbers in which they occur in a fossil state, and interesting from the peculiarities of structure whereby they are distinguished. The shells of these singular organisms (fig. 2) are divided into distinct compartments*, so as almost exactly to resemble in their form the camerated shells of the Nautili, Ammonites, and other highly-organized mollusca. Examined, however, in a living state, they are found to belong to animals of a very different type, as remarkable for the simplicity of their organization as for their elegance and delicacy. The shell, as represented in the figure, consists of numerous chambers divided from each other by calcareous septa, and perforated by innumerable minute orifices, or *foramina*, from which circumstance is derived the characteristic name. Internally these chambers are entirely filled with a homogeneous, transparent, glairy substance, which, being soft and diffluent, like the arms of *Gromia* described above,

Fig. 2.



1. *Nonionina*, exhibiting pseudopodia protruded through the foramina in the walls of the shell.
2. The same after the solution of the shell in weak acid.

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* Whence the group has also received the name of Polythalamia, *i.e.* many-chambered.

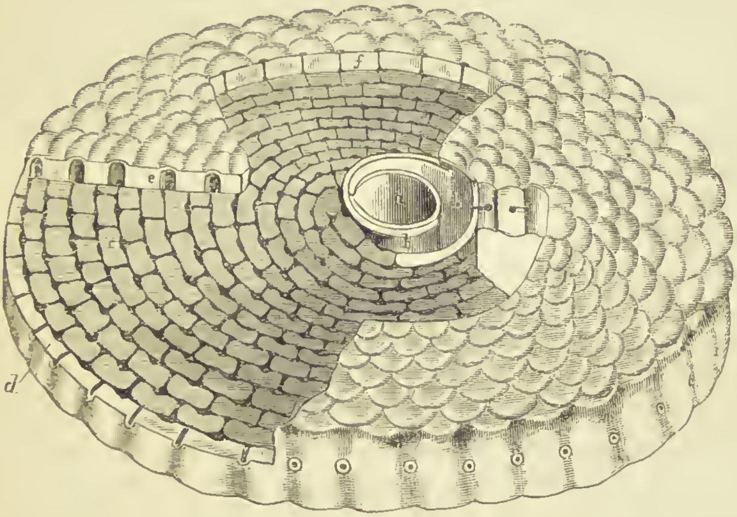
can be protruded through the numerous apertures in the periphery of the shell in the shape of long contractile filaments (*pseudopodia*).

(18.) On removing the delicate calcareous shell by the assistance of a weak acid, the body of the animal denuded of its covering (fig. 2, 2) is found to be entirely soft: that portion which is lodged in the first compartment of the shell is colourless and of a crystalline transparency; but in each of the succeeding segments there may be detected a granular mass of a brownish colour, and not unfrequently the minute silicious shells of *Naviculæ, Bacillariæ,* and other forms of Infusorial organisms, the remains of which may be traced nearly as far as the umbilicus of the spiral.

(19.) The pseudopodia of the Foraminifera probably entangle and lay hold of the minute bodies which serve as food, consisting of Diatomaceæ, Desmidieæ, the smaller forms of Confervæ, &c., and draw these by their contraction into the substance of the animal, within which they may be seen through the transparent shell. It is not by any means constantly that their indigestible residua are cast forth again, for they sometimes accumulate in such numbers as even to choke up a considerable part of the cavity. The living gelatinous substance is occasionally seen to extend itself around the exterior of the shell; and *pseudopodia* may then be put forth from this extension as well as from the ordinary outlets.

(20.) The Foraminifera are evidently composite fabrics evolved by a process of continuous gemmation, each gemma remaining in connexion with the body by which it was put forth; and according to the plan on which this gemmation takes place will be the configuration of the shell. Thus, if a bud should be put forth from one of these creatures in the direction of the axis of its body, and a second shell should be formed around this bud in continuity with the first, and this process should be successionally repeated, a straight rod-like shell will be produced, having many chambers communicating with each other by the openings that originally constituted their mouths, the mouth of the last-formed chamber being the only aperture through which the gelatinous body, thus composed of a number of segments connected by pedicles or stolons of the same material, can receive a supply of food. The successive segments may be all of the same size, or nearly so, in which case the entire rod will approach the cylindrical form, or resemble a line of beads; but it often happens that each segment is somewhat larger than the preceding, so that the composite shell has a conical form, the apex of the cone being the original segment, and its base the one last produced. If each of the successively formed segments instead of being developed exactly in the axis of its predecessor should be directed a little to one side, it is obvious that a curved instead of a straight rod will be the result; and this curve may be increased until it become a spiral. The character of this spiral will depend in a great degree upon the enlargement or non-enlargement of the successively formed chambers; for sometimes it opens out very rapidly, every whorl being considerably broader than that which it surrounds, in consequence of the great excess of the size of each segment over that of its predecessor (fig. 2, 1); but more commonly there is little difference between the successive segments after the spiral has made two or three turns. In many genera the new segments are added in concentric rings, each surrounding its predecessors, so as to form flattened disks varying in size from that of a pin's head to that of a sixpence. When such disks are subjected to microscopic examination, they are seen to be composed of concentric circles of cells (fig. 3) which communicate with each other by means of lateral passages, and which in the living state are each of them filled by the sarcode whereof the living portion of the animal consists. In this case there can be no reasonable doubt that the radial extensions of the outermost zone issue forth as pseudopodia from the marginal pores, and that they search for and draw in alimentary materials in the same manner as do those of other Foraminifera.

Fig. 3.



Structure of the calcareous disk of an Orbitolite:—*a*, the central cell; *b*, circumambient cell; c, c, concentric zones; *d*, *d*, annular passages of the outermost zone. The same parts are shown by a vertical section passing in a radial direction at *e*, *e*; and at *f*, *f*, following the course of one of the zones.

(21.) Where the growth of the disk takes place with normal regularity, it is probable that a complete circular zone is added at once. When the sarcode body has increased beyond the capacity of its enveloping disk, it may be presumed that its pseudopodial extensions proceeding from the marginal pores coalesce, so as to form a complete annulus of sarcode round the margin of the outermost zone; and probably it is by a deposit of calcareous matter in the surface portion of this annulus that the new zone of shelly substance is formed, which constitutes the walls of the cells and passages occupied by the soft sarcode body. Thus we find this simple type of organization giving origin to fabrics of by no means microscopic dimensions, in which, however, there is no other differentiation of parts than that concerned in the formation of the shell, every segment and every stolon (with the exception of the two forming the nucleus or centre) being, so far as can be ascertained, a precise repetition of every other, and the segments of the nucleus differing from the rest in nothing but their form. The equality of the endowments of each segment is shown by the fact (of which accident has frequently furnished proof), that a small portion of a disk entirely separated from the remainder will not only continue to live, but will so increase as to form a new disk, tho loss of the nucleus not appearing to be of the slightest consequenco from the time that active life is established in the outer zones.

(22.) In *Faujasina* and the *Nummulites*, apparently the most highly organized of the Foraminifera, the shell is of more complicated structure, being permeated by a system of radiating interseptal canals communicating with the exterior.

(23.) For the following observations relative to the reproduction of the Foraminifera we are indebted to Professor Max Schulze *.

Remarking that an individual of the genus *Triloculina* (D'Orbigny) had become stationary for several days, and enveloped, as is not usual, in a thin layer of brownish slime, Professor Max Schulze † paid particular attention to it. At the end of a few days after it had become quiescent, minute spherical, sharply defined granules were detached from the brownish slimy envelope, and in the course of a few hours the animal was surrounded with about forty of these corpuscles, which gradually became more and more separated from it. Microscopic examination proved that these were young Foraminifera. When viewed by transmitted light, they presented a pale-yellowish-brown calcareous shell, consisting of a central globular portion partly surrounded by a closely-applied tubular part, and having no septum in the interior. In a short time the young animals protruded their contractile processes from the anterior opening of the shell and crawled about upon the glass. The parts of the body contained within the shell could be examined with great accuracy under the highest magnifying powers, and were seen to consist of a transparent, very finely granular, colourless material, of which the protruded filaments were an immediate continuation. From tho circumstances under which the young Foraminifers made their appearance, they must necessarily quit their parent in a tolerably perfect condition.

(24.) When tho calcareous shell of the parent animal was carefully broken up, it was found to contain only trifling remains of a finely granular organic substance, which, after careful and continued observation, exhibited no trace of motion such as is often, under other circumstances, presented in separated particles of the animal substance, nor could he perceive any vestige of a young one in process of development. The almost complete absence of any organic contents in the shell of an individual which from eight to fourteen days previously was creeping about, renders it probable that the whole (or, at any rate, part) of its body had been transformed into young ones.

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* Müller's Archiv, 1856, p. 163.

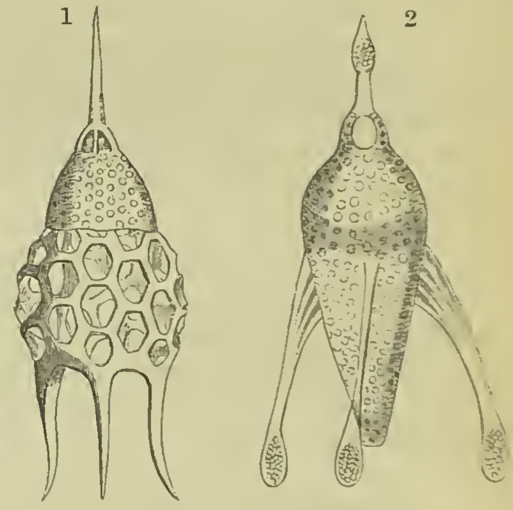
† Professor Max Schulze, Ueber den Organismus der Polythalamien (Foraminiferen). Leipzig, 1854.

(25.) It is astounding to reflect upon the multitudes of these microscopic shells which crowd almost every sea-beach. In some cases at least one-half of the bulk of the sand seems to consist of these elegant organisms. Plancus (Ariminensis, De Conchis minus notis) counted 6000 in a single ounce of sand from the shores of the Adriatic; and D'Orbigny estimated that an ounce of sand procured from the Antilles contained not fewer than 3,800,000! The numbers therefore contained in a square yard are beyond all human calculation; and yet, what is that when compared with the extent of sea-coast in all parts of the globe? Probably therefore no race of animals is more numerically important than that we are now considering. Their remains constitute a great proportion of the so-called sand-banks which often so materially interfere with navigation by obstructing the entrance to bays and straits, or, as is the case with the port of Alexandria, blocking up harbours. They enter largely into the formation of coral islands, and not unfrequently compose extensive geological deposits. One solitary species of the genus *Fusulina* has, in Russia, given rise to enormous beds of calcareous shells. The cretaceous formations both of France and England contain them in immense quantities. The tertiary strata abound with numerous species; and the very stones of which the largest of the Pyramids of Egypt is built are principally composed of shells (*Nummulites*) belonging to this important group. The tertiary basins of the Gironde, of Austria and of Italy, and more especially the "*calcaires grossiers*" of the vast Parisian basin, are in some parts so filled with them, that 58,000 have been counted in a cubic inch, or about 3,000,000,000 in a cubic yard—figures that may well spare us further calculation. In fact, it might be stated without exaggeration, that the city of Paris, as well as many of the towns and villages in the surrounding departments, are almost entirely built of stones that seem to be mere agglomerations of these microscopic shells.

(26.) The substance of the shell in the Foraminifera varies to a certain extent in accordance with its mode of growth. When the calcareous investment is made up of segments involving each other, it is of a dense texture, resembling porcelain. When the segments alternate without a spire, or when the spiral revolution is oblique, the shell is porous, and perforated, more especially in the last-formed compartments, by numerous apertures through which the *pseudopodia* are protruded. When the segments are all placed in a straight line, or when they are rolled in a spiral upon the same plane, or when they are alternate and the shell is inequilateral, their texture is very generally transparent like glass [*].

(27.) Nearly related to the Foraminifera, or at least apparently belonging to the same general type of structure, are the *Polycystina*, an extensive group of very interesting microscopic bodies possessing great beauty and variety of form and structure. These are minute silicious shells, which appear, from the recent observations of Professor Müller [†], to contain in the living state an olive-brown sarcode extending itself into pseudopodial prolongations that pass through the large apertures by which the shells are perforated. The sarcode does not seem always to fill the shell, but only its upper part or vault, and to be very regularly divided into four lobes. It is a peculiar feature in these Polycystina that their shells are often prolonged into spines or other projections, which are sometimes arranged in such a manner as to give them a very singular aspect (fig. 4). It seems probable that these creatures are at the present time as widely diffused as the Foraminifera, although, from their extreme minuteness, they have not been so often recognized. They were first discovered by Professor Ehrenberg at Cuxhaven, on the North Sea; they were afterwards found by him in collections made in the Antarctic seas; and have been recently described by Professor Bailey as presenting themselves (with Foraminifera and Diatomaceæ) in the de-

Fig. 4.



1. Podocystis Schomburgkii.
2. Rhopalocanium ornatum.

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[*] The following table indicates the proportions of genera and species of Foraminiferous shells which have been met with in various geological epochs:—

Carboniferous series	1 genus,	1 species;
Jurassic series	4 genera,	20 ,,
Cretaceous series	30 ,,	250 ,,
Tertiary series	55 ,,	460 ,,
Now existing	68 ,,	900 ,,

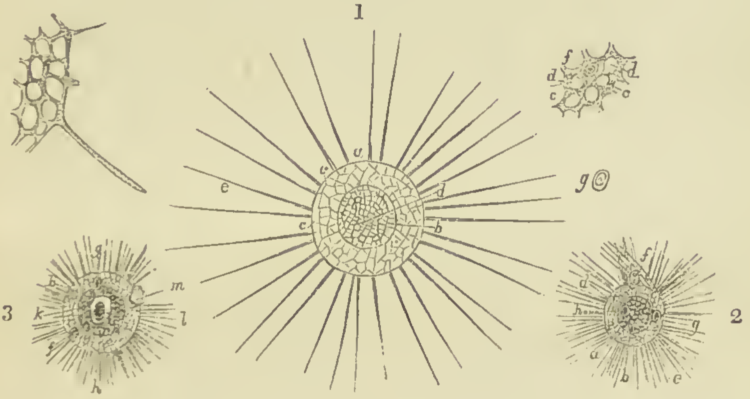
so that 1631 species of these minute organisms have already been distinguished by classical naturalists.

[†] *Vide* Müller, über die Thalassicollen, Polycystineen und Acanthometren des Mittelmeeres, in Monatsbericht der Königl. Akademie der Wissenschaften zu Berlin, 13 Nov. 1856.

posits brought up by the sounding-lead from the bottom of the Atlantic Ocean at depths of from 1000 to 2000 fathoms. They appear to have been much more abundant, however, during the later geological periods, inasmuch as in a single deposit in Barbadoes, Professor Ehrenberg detected no fewer than 282 forms which he considers to be specifically distinct.

(28.) Actinophrys.—Among the most interesting contributions to our knowledge of these simple organisms are those of the distinguished German micrologist Kölliker, whose researches relative to the organization of *Actinophrys Sol** are calculated to clear up many doubtful points connected with the physiological history of numerous allied genera of kindred structure. The Actinophrys (fig. 5, 1) is a minute animalcule nearly spherical in its shape, having the surface of its body covered with closely-set delicate filaments, the length of which frequently exceeds the diameter of the creature. It does not present a trace of mouth, stomach, intestine, or anus, but consists entirely of a perfectly homogeneous substance of soft and delicate consistence. Examined under a very high power, the whole animalcule appears to be made up of a most regular and delicate tissue of round or polygonal cells, although on closer inspection such is found not to be really the true structure. When the animal is torn or crushed, it becomes evident that it is entirely composed of a semifluid material (*sarcode*) enclosing vacuoles; for it will be found that the supposed cells may at pleasure, under pressure,

Fig. 5.



Actinophrys Sol.—1. *a*, the cortex; *b*, nucleus of the animalcule; *c*, homogeneous basal substance; *d*, vacuoles; *e*, tentacular filaments. 2. The same, less magnified, at the moment of feeding:—*a*–*e*, as above; *f*, an infusorium which has just entered the substance of the body, while the surrounding filaments enclose it on all sides. 3. Another specimen:—*a*–*e*, as in fig. 1; *f*, a *Vaucheria*-spore wholly imbedded in the cortical substance, the opening through which it entered entirely closed, although its situation is indicated by a slight depression; *g*, another spore already entering the nuclear substance; *h*, an infusorium lying in a special cavity; *i*, a spore in the nuclear substance; *k*, half-digested morsels; *l*, a swallowed *Lynceus*; *m*, excrementitious matter beginning its exit from the cortical substance. The other figures represent the sarcode highly magnified.

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* Siebold and Kölliker's Zeitschr. vol. i. p. 198.

be made either to coalesce into larger or be divided into smaller cavities presenting in all respects the character of the normal ones.

The filamentary appendages to the periphery of this animalcule are essentially tentacular organs, composed of the same substance as the rest of the body, from which they differ only in never having vacuoles in their interior; and if granules are to be detected in their structure, these are very few in number.

(29.) The mode in which the Actinophrys is nourished is a subject of the highest interest. Although, as has been stated, the creature has neither mouth nor stomach, yet it lives upon solid nutriment and rejects such parts as are indigestible. The Actinophrys, indeed, feeds upon Infusoria of all kinds, on the lower Algæ, such as the Diatomaceæ, and even on minute Crustacea, as the young of *Lynceus*, *Cyclops*, &c., which it accomplishes in the following manner:—When, in its progress through the water, it comes in contact with fitting food, the object, whether of animal or vegetable nature, as soon as touched by one of the tentacular filaments, usually becomes adherent thereunto. The filament, with prey thus attached, then slowly shortens itself, dragging the object seized towards its devourer,—all the surrounding filaments bending their points together, so that the captive becomes at last enclosed on every side (fig. 5, 2, *f*).

(30.) That the tentacles, however, possess some other power than that of mere prehension appears evident, because nearly every creature of moderate and even immoderate size which strikes against them is at once for a time rendered immoveable. When a Rotifer, in crossing the field with velocity, strikes against any object, the rotatory organ is often seen at once to suspend its operation, more particularly should its cilia strike the cilia of another animalcule; and frequently no notice whatever is taken of the shock; not so, however, with the victim of the *Actinophrys Sol*, on the instant of contact with whose tentacles it appears to be paralysed.

In some cases the prisoner is held for some seconds on the exact spot where it struck, and then, without any visible means, becomes attracted towards the body of the Actinophrys, gliding slowly down the tentacle until it is jammed between its base and a neighbouring one. In other instances, instead of the prisoner being arrested on or near the extremity of the tentacle on which it strikes, it is shot down to the base with extreme rapidity, to occupy the same position as in the former case. Sometimes it would seem as if the appetite of the Actinophrys were sated, or that the captive was not approved of, for after remaining stunned for a few seconds, ciliary action is feebly recommenced, not sufficient to produce motion, but as if a return to vitality had been effected; shortly it is seen to glide off the tentacle (as if that organ possessed the power both of appropriation and rejection), and frequently, with but little sign of recovered life, it floats out of the field.

(31.) But should the Actinophrys be hungry, the spot upon which the captured animalcule is lying slowly retracts, and forms at first a shallow depression, in which the prey, apparently adherent to the surface and following it in its retraction, is finally lodged. The depression, by the continued retraction of the substance, becomes deeper; the imprisoned animalcule, which up to this time had projected from the surface of the Actinophrys, entirely disappears within it, and at the same time the tentacula, which had remained with their extremities applied to each other, again erect themselves and stretch out as before the capture. Finally, the depression assumes a flask-like shape by the drawing-in of its margin, the edges of which coalesce, and thus a cavity closed on all sides is formed wherein the prey is lodged. In this situation it remains a longer or shorter time, gradually, however, approaching the central portion of the body. In the mean time the periphery of the Actinophrys regains in all respects its pristine condition. The engulfed morsel is gradually digested and dissolved, as is readily seen by its change of appearance from time to time. If entirely soluble, as, for instance, an Infusorium, the space in which it is contained contracts as the dissolution of its contents goes on, and finally disappears altogether: should there, however, be an indigestible residue, a passage for its exit is formed, and it is expelled by renewed contractions of the homogeneous substance, and in the same direction, or nearly so, as that which the morsel followed in its introduction. The passage and the opening through which the expulsion was effected disappear again without leaving a trace.

(32.) The number as well as the size of the morsels taken at one time, in the manner above described, by an Actinophrys, is very various. Sometimes there may be two, four, or six swallowed simultaneously; occasionally more than ten or twelve.

(33.) A remarkable contractile vesicle is always visible in these animalcules, which Mr. Weston* regards as a valvular orifice. It is best distinguished when about the edge of the *seeming disk*, and is never still night nor day, being slowly but without cessation protruded, occupying from ten to seventy or eighty seconds in its development, and then, like the bursting of a vesicle, rapidly and totally subsiding: for an instant it totally disappears, but only to be as gradually and as certainly reproduced. Should that side of the creature where the valve is placed be turned from the observer, the *effects* of the contraction are distinctly seen, although the valve itself is not; for at the instant of its bursting and closure, some half a dozen or more of the tentacles *situated on or about it,* which have been gradually thrust from their normal position by the act of its protrusion, now approach each other with a jerk-like motion caused by the sudden bringing together of their bases.

(34.) The valve seems to be formed of a double layer of the external hyaloid membrane, the edges of which appear to adhere to each other tenaciously, notwithstanding the growing distension from within, until the force becomes so great that the lips, as they may be called, suddenly separate, apparently to give vent to some gaseous product.

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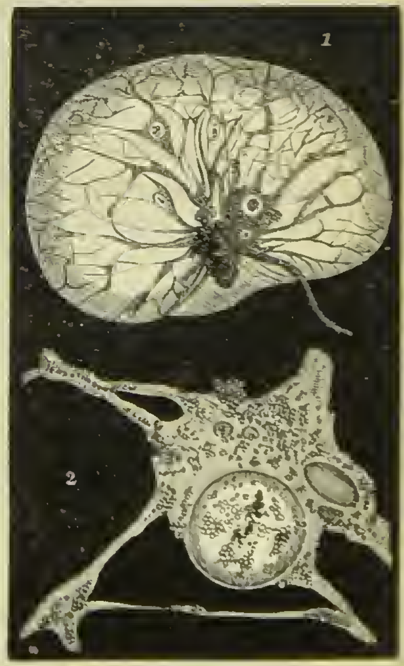
* Quarterly Journal of Microscopical Science, vol. iv. p. 116.

(35.) With regard to the reproduction of the species, Mr. Weston assures us that self-division is one mode. First may be noticed a deep depression above and below, not far from the centre of the body; this, as it increases, throws the tentacles across each other, as a necessary consequence of the depressions in the surface and the position into which the outer membrane (in which the tentacles are inserted) is drawn. As the division proceeds, the two animals steadily, but rather quickly, increase the distance between them, until there is only a long membranous neck, apparently composed first of four, then three, then two irregular lines of cells, which ultimately diminish into a single cord composed of three simple cells, elongated like the links of a chain, and becoming more attenuated till the division is complete. All this latter part of the process is rather rapidly performed; that is, from the first formation of the rows of cells to the time of the final separation occupies only about a quarter of an hour.

(36.) The Noctilucæ may perhaps be classed with the Rhizopods. The general shape of the Noctiluca* (fig. 6, 1) is that of a minute melon deeply indented at one extremity, at which point is attached a sort of proboscidiform appendage or tail: externally its body seems to consist of two membranes of extreme delicacy, which are apparently filled with a clear fluid. At the bottom of the indentation above-mentioned, close to the insertion of the appendix, there is always found a little mass of mud, or other detritus, which it is very difficult to wash away; but when this is accomplished, it becomes perceptible that this foreign matter is adherent to a semitransparent granular substance, which here protrudes through a little aperture generally called the mouth, and which is continuous with a quantity of the same material situated in the interior of the little globe. No digestive apparatus is visible; but numerous vacuoles of variable size (fig. 6, 2) are discovered in the granular substance within, together with a central nucleus. No rhizopodic

Fig. 6.



1. *Noctiluca*, magnified, and viewed as a transparent object. 2. A portion of its internal tissue magnified 150 diameters, showing vacuoles and rhizopodic expansions.

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* M. de Quatrefages, Observations sur les Noctiluques. Ann. des Sc. Nat. 1850.

expansions are in those organisms protruded externally; but in the interior the microscope reveals a delicate network of irregular filaments that ramify in every direction, and exactly resemble in their character the anastomosing threads of *Gromia*, represented in a preceding figure.

(37.) In the vacuoles it is easy to perceive particles of green matter or other foreign substances, which seem to afford nourishment to the animal; so that these cavities doubtless perform the functions of temporary stomachs, although they are constantly changing their shape and situation in a most remarkable manner.

(38.) No reproductive apparatus is apparent in these little beings; yet sometimes individuals are to be seen with double bodies, and, from the observations of Colonel Baddeley as recorded by Mr. Brightwell*, there seems to be little doubt that the Noctiluca multiplies by spontaneous fissure. Colonel Baddeley's researches lead him to infer that this process "begins by the gradual formation of a second nucleus, which after its commencement rapidly arrives at the size and appearance of the other. A second globular substance also (termed by some previous writers on the subject the *mouth*) is formed, in addition and near to the nucleus; and a constriction, small at first, but gradually increasing, takes place, until the perfect Noctilucæ are developed, united at last by a thin band which is speedily ruptured,—the whole process of division not occupying more than twelve hours." The observations of Dr. Busch†, and more particularly those of Mr. Gosse‡, clearly demonstrate that the Noctilucæ increase also by germs or gemmæ.

(39.) It will surprise some of our readers to find that the Noctilucæ, small as they are, feed upon Diatomaceæ, and that in these microphagists we have the means of supplying our cabinets with specimens of some of the rarer forms. Colonel Baddeley observes that he finds that, when newly captured, each Noctiluca has several Diatoms in its interior, lying in the various chambers or pouches distributed through the body of the animal. These Diatoms all disappear in a few days, leaving nothing visible but the vacuoles or alimentary sacs filled with granular particles. A very careful examination shows an orifice near the *tail* or peduncle, the opening of which may be detected by carefully pressing it; and from this is protruded, by continuous gentle pressure, a very thin hyaline sac, filling gradually with fluid and small granular particles, till it attains about one-third of the size of the animal, when it bursts and disappears.

(40.) The name *Noctiluca* is indicative of the extraordinary faculty that these little creatures possess of emitting a brilliant phosphorescent light. When a vase filled with sea-water containing them is placed in a dark chamber, the slightest agitation is sufficient to excite this phenomenon, and the smallest undulations upon the surface are indicated by luminous circles. On examining one of the animalcules attentively with the microscope, it is further observable that the light given out is not universally diffused through the substance of its body, but is confined to minute luminous points scattered here and there, which make their appearance in rapid succession and as suddenly vanish; so that evidently there is no special organ to which the luminous appearance can be referred, as in the case of the glow-worm and other phosphorescent creatures. In size these stars of ocean are almost microscopic, the largest of them not much exceeding the dimensions of a pin's head: but the amazing numbers in which they crowd the billows amply makes up for their minuteness; at certain seasons, indeed, it may be literally said that every drop of every wave contains one or more individuals belonging to the brilliant host. On taking up at random a flask of sea-water, and allowing the little creatures to accumulate, as they always do when at rest, at the top, it will be seen that their bodies will form a stratum equalling in thickness from one-seventh to one-third part of the entire contents of the vessel. After such demonstration as this, it is easy to comprehend how the entire sea, rendered luminous by the presence of Noctilucæ, seems to burn with phosphorescent fire. When the surface is tranquil in some well-sheltered bay, these living gems form a kind of cream of liquid light; or if a wave disperses their myriads and at the same time calls forth by agitation all their brightness, it is easy to imagine how a flame is thus evoked that spreads for miles. giving at a distance the appearance of a uniform sheet of light, but, when closely examined, resolvable, like the nebulæ in the firmament, into constituent stars.

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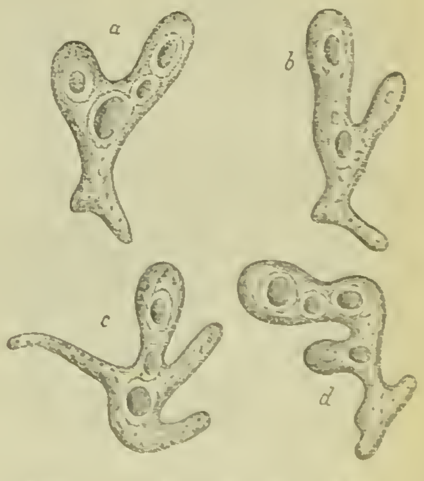
* Quarterly Journal of Microscopical Science, vol. v. p. 186.

† Microscopical Journal, vol. iii. p. 203.

‡ Rambles on the Devonshire Coast, p. 257.

(41.) Amœbæ.—Very nearly allied to the Rhizopods in their organization are certain minute gelatinous beings found in our fresh waters, which have long been puzzles to the microscopist, and a fruitful theme of discussion among naturalists (fig. 7). These creatures appear under a good glass as minute patches of transparent jelly, having, under ordinary circumstances, a diameter of from $\frac{1}{300}$th to $\frac{1}{600}$th of an inch, but remarkable for perpetually changing their form—at one time shrinking into the appearance of a little globe, then expanding into a flattened radiating disc, and again shooting out processes of their substance in various directions, so as to assume all sorts of shapes with the greatest

Fig. 7.

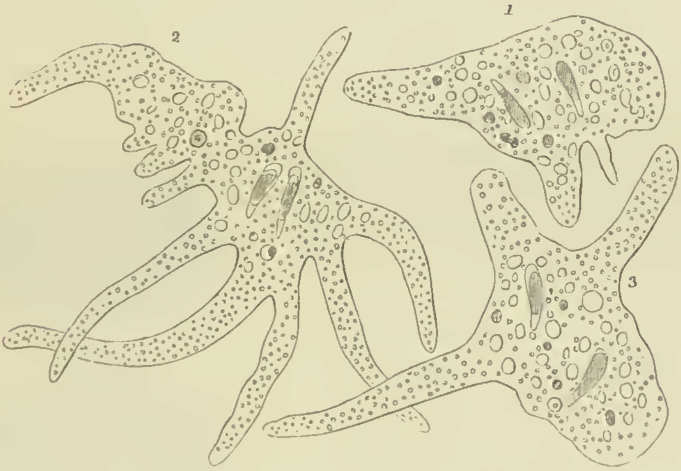


Amœba, showing the vacuoles in its sarcodic substance. *a, b, c, d*, some of the various shapes which it assumes.

facility, deserving well the names of *Proteus* and *Amœba* bestowed upon them by zoologists.

(42.) When a drop of water containing these creatures is placed beneath the microscope, the observer at first discovers nothing but a few semitransparent or cloudy-looking motionless globules, from which flows, as from a drop of oil, a kind of semifluid stream, which, fixing itself upon the object-glass, seems to draw the entire mass slowly after it. In this way numerous expansions make their appearance from different parts of the body, which after spreading to a little distance again shrink and become completely blended with the central portion. The young Amœbæ are perfectly diaphanous, and with difficulty perceptible except under favourable circumstances; but as they become older they lose this transparency in consequence of the accumulation of foreign particles in their interior, which seem to have been introduced from without by the simple pressure of the semifluid body of the animalcule as by the contractions and expansions of its various portions it crawls or rather flows over them.

Fig. 8.



Amœba princeps (Ehr.), magnified 300 diameters. The figures 1, 2, 3 exhibit the same animal and its protean changes of form.

There are, however, other corpuscles or granules, besides those above indicated, found in the interior of these creatures. Some, extremely minute and irregular in their shape, appear to differ only in density from the surrounding glutinous substance, and these are considered by Dujardin to be rather products of secretion than ova. They move about, appearing to flow in accordance with the variable expansions of the creature which contains them. But besides these, in large specimens of Amœbæ, other granules are met with (fig. 8, 1, 2, 3), which on account of the uniformity of their appearance might with more plausibility be regarded as reproductive germs; but their nature is very doubtful. The Amœbæ are capable of multiplication by spontaneous fissure, or by detaching a lobe from their bodies, which will continue to live upon its own account just as well as when forming a part of the original animalcule. On cutting one of these creatures in two, or tearing it to pieces, there is no escape of fluid perceptible; but each portion contracts itself, and commences a separate individuality.

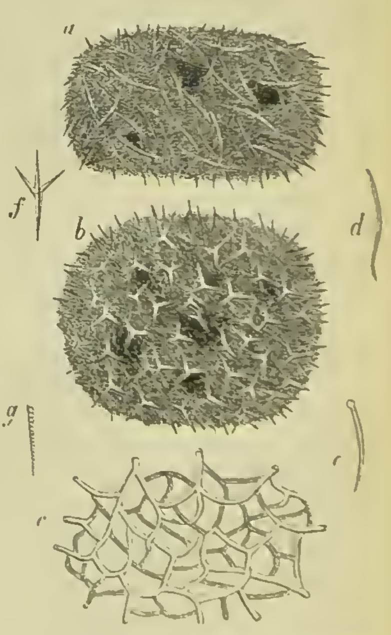
(43.) In one species of *Amœba* (*A. verrucosa*, Ehr.) Mr. Carter* has witnessed ovular development, the Amœba perishing as the ovules are perfected, and ending in becoming a mere ovisac. When first formed, the ovules, which are spherical, consist of a hyaline capsule enclosing a sphere of glairy, refractive fluid; but as they begin to increase, this glairy matter becomes transformed into a granuliferous mucus which is spread over the inner surface of the capsule; and finally the granules present motion—whether of themselves or by the aid of the mucus in which they are imbedded is uncertain. The history of their further development has not yet been made out; but Mr. Carter thinks that the next stage of their growth consists in the whole ovule becoming polymorphic.

(44.) Sponges.—However dissimilar apparently, both in form and structure, from the simple organisms described above, it is in their immediate vicinity that we must place the extensive group of Sponges, which has until recently held a very dubious position upon the confines of the animal and vegetable kingdoms.

(45.) The common sponge of commerce is, as every one knows, made up of horny, elastic fibres of great delicacy, united with each other in every possible direction, so as to form innumerable canals which traverse its substance (fig. 9, *c*). To this structure the sponge owes its useful properties, the resiliency of the fibres composing it making them, after compression, return to their former state, leaving the interstitial canals open, to suck up surrounding fluids by capillary attraction.

(46.) The dried sponge is, however, only the skeleton of the fabric. In its original state, before it was withdrawn from its native element, every filament of its substance was coated over with a thin film of glairy, semifluid matter that constitutes the living part of the sponge, secreting, as it extends itself, the horny fibres which are imbedded in it.

Fig. 9.



Spicula and horny skeleton of various Sponges.

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* Ann. & Mag. Nat. Hist. 2nd ser. vol. xx. p. 37.

(47.) Many species, although exhibiting the same porous structure, have none of the elasticity of the officinal sponge, a circumstance to be attributed to the difference observable in the composition of their skeleton or ramified framework. In such, the living investment forms within its substance not only tenacious bands of animal matter, but great quantities of crystallized spicula, sometimes of a calcareous, at others of a silicious nature, united together by the tenacity of the fibres with which they are surrounded. On destroying the softer portions of these skeletons either by the aid of a blowpipe or by the caustic acids or alkalies, the spicula remain, and may readily be examined under a microscope: they are then seen to have determinate forms, generally in relation with the natural crystals of the earths of which they consist; and as the shape of the spicula is found to be similar in all sponges of the same species, and not unfrequently peculiar to each, these minute particles become of use in the identification of these bodies.

(48.) Crystallized spicula of this description form a feature in the structure of the sponge which is common to that of many vegetables, resembling the formations called *raphides* by botanical writers. Some of the principal forms they exhibit* are depicted in fig. 9, *a*, *b*, *d*, *e*, *f*, *g*, which likewise will give the reader a general idea of the appearance of the silicious and calcareous sponges after the destruction of their soft parts has been effected by the means above indicated. The figures *d*, *e*, *f*, and *g* likewise represent detached spicula of different shapes highly magnified. The most convenient method of seeing them is, simply to scrape off a few particles from the incinerated sponge upon a piece of glass, which, when placed under the microscope, may be examined with ordinary powers.

(49.) On placing a living sponge of small size in a watch-glass or small glass trough filled with sea-water, and watching it attentively, something like a vital action becomes apparent †. The entire surface is seen to be perforated by innumerable pores and apertures, some exceedingly minute, opening on every part of its periphery; others of larger dimensions, placed at intervals, and generally elevated upon prominent portions of the sponge. Through the smaller orifices the surrounding water is continually sucked as it were into the interior of the spongy mass, and it as constantly flows out in continuous streams through the larger openings. The annexed diagram, fig. 10, A, will give the reader an idea of the most usual direction of the streams. The entering fluid rushes in at the countless pores distributed over the general surface of the sponge, but in its progress through the canals in the interior becomes directed into more capacious channels, communicating with the prominent larger orifices, through which it is ultimately ejected in equable and ceaseless currents. Organized particles, such as necessarily abound in the water of the ocean, are thus introduced into the sponge on all sides, and are probably employed as nutriment, whilst the superfluous or effete matter is continually cast out with the issuing streams as they rush through the fecal orifices. The growth of the sponge is thus provided for; the living gelatinous portion continually accumulates and, as it spreads in every direction, secretes and deposits, in the form peculiar to its species, the fibrous material and earthy spicula constituting the skeleton.

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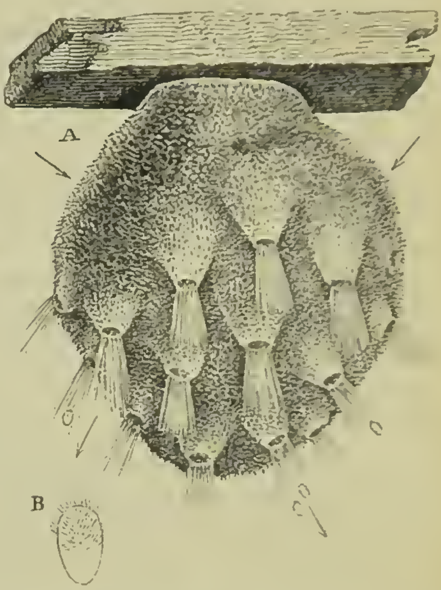
* Savigny (Jules César), Zoologie d'Égypte: gr. fol. Paris, 1809.

† Dr. Grant, in the New Edinburgh Philosophical Journal, 1827.

Fig. 10.



A, a common Sponge: the arrows indicate the direction of the entrant and issuing currents. B, a ciliated gemmule magnified.

(50.) It is by no means easy to explain the cause of the perpetual flow of water through the substance of the sponge in currents so powerful and so constant. In the various species of *Grantia*, however, Mr. Bowerbank and Dr. Dobie have succeeded in detecting the presence of cilia. These sponges have a very simple structure, each being a sort of bag, whose walls are so thin that no system of canals is required, the water absorbed by the outer surface passing directly towards the inner, and being expelled from the mouth of the bag. The cilia may be plainly seen with a $\frac{1}{5}$th inch objective on the cells of the gelatinous substance scraped from the interior of the bag, or they may be observed *in situ* by making very thin sections of the substance of the sponge.

Mr. Bowerbank*, however, has satisfactorily proved that some sponges possess a power of opening and closing the oscula at pleasure. He found that in a specimen of *Spongilla fluviatilis* about half an inch in diameter, which had attached itself to a watch-glass, there was at the summit of a large oval inflation a single osculum, which opened or closed according to the necessities of the animal, and from which, when in full action, a constant stream of water was poured forth. The inhalation of the water by the porous system presented some remarkable peculiarities: when in a state of repose, the dermal membrane appeared to be completely imperforate; but when about to commence vigorous inhalant action, a slight perforation appeared here and there over its surface, the orifices gradually increased in size until the full diameter of the pores was attained, and their margins then became thickened and rounded. On a little indigo being diffused in the water, it was seen to be absorbed with avidity; and the inhalant action continued for a considerable period, the interior of the sponge becoming strongly coloured with indigo.

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* Quarterly Journal of Microscopical Science, vol. vi. p. 78.

After a time the rapid inhalant process ceased, either abruptly or gradually, a very languid action only remained, and nearly the whole of the pores were closed. When this operation was about to take place, the rounded margin of the orifice lost its form and became thin and sharp, while the circumference gradually melted inwards until the orifice entirely closed, and not a vestige of the organ previously existing remained: the operation of closing occupied rather less than a minute. When once closed, these orifices do not appear to be reopened, but fresh pores are produced. The colouring matter absorbed during the period of active inhalation was apparent in the sponge from twelve to eighteen hours; and during this period the stream from the osculum was extremely languid. The structure and habits of the freshwater Sponges are entirely in accordance with those of marine species.

(51.) From this description of the structure of a sponge, it will be apparent that all parts of the mass are similarly organized: a necessary consequence will be, that each part is able to carry on, independently of the rest, those functions needful for existence. If therefore a sponge be mechanically divided into several pieces, every portion becomes a distinct animal.

(52.) In *Cliona celata*, one of the freshwater sponges, M. Dujardin* discovered, mixed up amongst the pin-like spicula that constitute their skeleton, irregularly shaped globules, composed of a contractile glutinous substance, which, when examined under the microscope, were seen continually to change their shape, presenting a constantly varying outline, exactly similar to what is witnessed in the protean animalcule, *Amœba diffluens*, above described; and to this contractile substance, whereof the living substance of the sponge seems principally to consist, he proposed to give provisionally the name of *Halisarca* (sponge-flesh †). Subsequent observations have shown that these proteiform bodies are not only thus changeable in their shape, but are able to exercise a distinct power of locomotion by agitating long flagelliform filaments that are appended to their bodies (fig. 11, 1); in fact, the whole of the living portion of the sponge seems to be made up of agglomerations of these amorphous bodies, spread over the spicula or skeleton of the sponge, all individually capable of changing their form by emitting processes in different directions, so as to increase their means of contact with the surrounding fluid, from which they evidently derive materials for assimilation.

(53.) These *sponge-cells*, as they are called by Mr. Carter ‡, are about the $\frac{1}{1000}$th part of an inch in diameter. If one of them be selected for observation, it will be found to be composed of its proper cell-wall, a number of granules fixed to its upper and inner surface, and towards its centre generally one or more hyaline vesicles.

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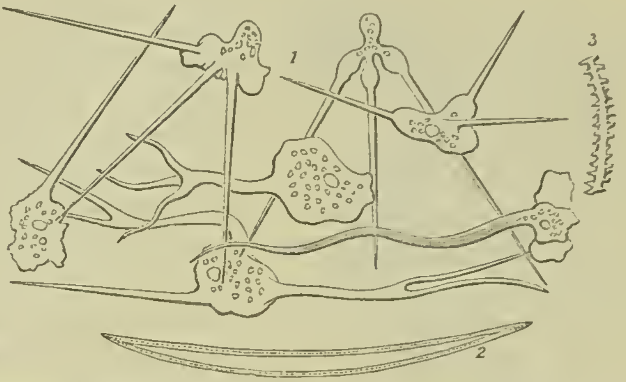
* Ann. des Sc. Nat. tom. x. 1838.

† Lit. "sea-flesh."

‡ On the Freshwater Sponges of Bombay, Ann. Nat. Hist. 1849.

Fig. 11.



1. Remarkable forms assumed by Proteans developed from the matter of the seed-like bodies of *Spongilla*, magnified. 2. General form of large spiculum. 3. Spiniferous spiculum. (After Mr. H. J. Carter).

(54.) The granules are round or ovoid, translucent, and of an emerald- or yellowish-green colour, varying in diameter below the $\frac{1}{13,000}$th part of an inch, which is the average linear measurement of the largest. In some cells they are so minute and colourless as to appear only under the form of a nebular mass, while in others they are of the largest kind, and few in number.

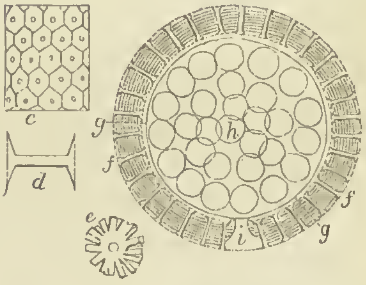
(55.) The hyaline vesicles, on the other hand, are transparent, colourless, and globular, and, although variable in point of size like the green granules, are seldom recognized before they much exceed the latter in diameter. They generally possess the remarkable property of slowly dilating and suddenly contracting themselves, and present, in their interior, molecules of extreme minuteness in rapid commotion.

(56.) The sponge-cell when *in situ* is constantly changing its form, both partially and wholly; its granules also are ever varying their position, in unison with, or independently of, the movements of the cell: and its pellucid vesicle or vesicles may be seen dilating or contracting themselves, or remaining passively distended, exhibiting in their interior the molecules above mentioned in rapid commotion. When first separated from the common mass, an isolated cell for a short time assumes a globular form, and afterwards, in addition to its becoming polymorphic, evinces a power of locomotion; it emits expansions of its cell-wall in the form of obtuse or globular projections or digital and tentacular prolongations. If in progression it meets with another cell, both combine; and if more are in the immediate neighbourhood, they all unite together into one globular mass. Should a spiculum chance to be placed in the path of a cell thus in motion, it will ascend it and traverse it from end to end, subsequently quitting it; or else, assuming its globular form, it will embrace some part of the spiculum and remain stationarily attached to it. The changes in shape and position of the sponge-cell are for the most part effected so imperceptibly that they may be likened to those which take place in a cloud. Its granules, however, are more active; but there appears to be no motion in any part of the cell (excepting among the molecules within the hyaline vesicle) which in any way approaches to that characteristic of the presence of cilia.

(57.) The intercellular substance that forms the bond of union between the sponge-cells is of a mucilaginous appearance. When observed in the delicate pellicle which, with its imbedded cells, it forms over the surface and throughout the canals of the sponge, it is transparent; but when a portion of this pellicle is cut off from its attachments, it collapses and becomes semi-opake. In this state the detached portion immediately evinces a tendency to assume a spheroidal form; but whether the intercellular substance participates in this act or remains passive while the contraction is wholly performed by the habit of the cells imbedded in it to approximate themselves, is not evident.

(58.) The freshwater sponges are reproduced from seed-like bodies found in the substance of the oldest or first-formed portions of the sponge, never in its periphery. They are round or ovoid according to the species, and each presents a single infundibular depression on its surface which communicates with the interior. At the earliest period of development at which it is recognizable, it is composed of a number of cells united together by an intercellular substance similar to that described above. In this state, apparently without any capsule, and about half the size of the fully developed seed-like body, it seems to lie *free* in a cavity formed by a condensation of the common structure of the sponge immediately surrounding it. The cells of which it is now composed appear to differ from those of the fully-developed sponge-cell only in being smaller, in the colourless state of their contained granules, and in the absence of hyaline vesicles. The seed-like body gradually passes from the state just mentioned into a more circumscribed form, then becomes surrounded by a soft, white, compressible capsule, which finally thickens, turns yellow, and developes upon its exterior a firm crust of silicious spicula, presenting in some species a hexagonally tessellated appearance (fig. 12, *c*). The spicula are arranged perpendicularly to the surface of

Fig. 12.



Magnified section of a seed-like body of *Spongilla Meyeni*, showing, *f*, spicular crust; *g*, coriaceous capsule; *h*, internal cells; *i*, infundibular opening. *c*, portion of coriaceous membrane, magnified, to show the hexagonal divisions with transparent centres; *d*, small spiculum, magnified; *e*, one of its toothed disks with central aperture, magnified. (After Mr. H. J. Carter.)

the capsule, and the interval between them is filled up with a white, silicious, amorphous matter which keeps them in position. Each spiculum extends a little beyond this matter, and supports on its free end a toothed disk, similar to a corresponding one on its fixed end, which rests on the capsule, so that the external surface of the seed-like body is studded with little stellate plates (fig. 12, *d*, *e*). In other species, where there appears to be no such regular arrangement of these spicula, a number of smooth spiniferous points is presented.

(59.) If a seed-like body which has arrived at maturity be placed in water, a white substance will after a few days be observed to have issued from its interior, through the infundibular depression on its surface (fig. 12, *i*), and to have glued it to the glass: if this be examined with the microscope, its circumference will be found to consist of a semitransparent material, the edge of which is notched or extended into digital or tentacular prolongations, precisely similar to those of the protean cell, which in progression or in polymorphism throws out parts of its substance in the same way. In the semitransparent substance may be observed hyaline vesicles of different sizes, contracting and dilating, as well as green granules, so grouped together as almost to enable the practised eye to distinguish *in situ* the passing forms of the cells to which they belong. Subsequently to the development of this fleshy substance comes that of the horny skeleton and its spicula (fig. 11, 2), which are at first membranous, and at an early period of their development pliable; they afterwards become firm and brittle. They are hollow, and the form of their cavity corresponds with their own shape; sometimes, moreover, they contain a green matter like the endochrome of the cells of Confervæ*.

(60.) In the genus *Tethya*, Mr. Huxley has described a true sexual generation to exist,—a portion of the spongy mass being found to consist of a granular substance in which ova and stellate crystalline bodies are imbedded. "The ova are of various sizes; they have a very distinct vitellary membrane, which contains an opake, coarsely granular yelk. A clear circular space, about $\frac{1}{1600}$th of an inch in diameter, marking the position of the germinal vesicle, is seen in each ovum, and within this a vesicular germinal spot $\frac{1}{5000}$th of an inch in diameter is sometimes visible. The stellate bodies are about $\frac{1}{2000}$th of an inch in diameter. The granular uniting substance is composed entirely of small circular cells about $\frac{1}{3300}$th of an inch in diameter, and of spermatozoa in every stage of development from those cells. The cell throws out a long filament which becomes the tail of the spermatozoon, and, becoming longer and more pointed, itself forms the head. It is remarkable that the ova are in no way separated from the spermatozoa, but lie imbedded in the spermatic mass like eggs packed in sand*."

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* Besides the seed-like bodies above described, other reproductive bodies are met with in *Spongilla*:—1. some which, from their resemblance to the motile spores or zoospores of many plants, have also been termed swarming-spores (*Schwärmsporen*); and 2. others which, from their resemblance to the spermatic filaments elsewhere met with, are denominated zoosperms.

(61.) The multiplication of marine sponges, however, is effected in

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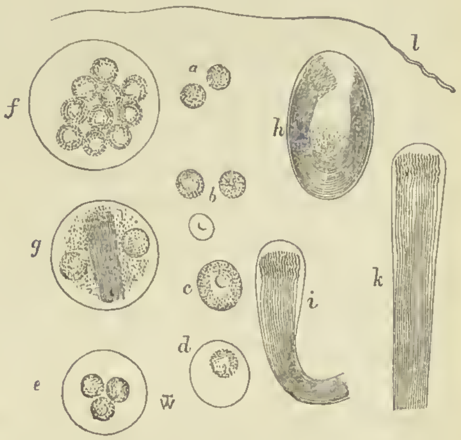
* The Spermatozoa, until recently considered as animalcules, generally present themselves under the form of long slender filaments or corpuscles, the shape of which varies to a remarkable extent, and nevertheless is so constant in individuals belonging to the same species that it is frequently possible to identify by their form the particular creature to which each modification is peculiar. Generally speaking, among the higher animals the Spermatozoa are found to consist of an extremely attenuated linear body, either filiform throughout or swollen and enlarged at one end, so as to present something like the appearance of a microscopic tadpole (fig. 13, *l*). They are exceedingly minute, seldom exceeding a line in length, but much more generally of far smaller dimensions, so that the highest powers of the microscope are requisite for their examination. These microscopic atoms may be regarded not merely as abounding in the seminal secretion of all animals, but in fact as constituting that important agent,—the presence of a fluid or liquor seminis appearing, when regarded in a physiological point of view, merely the vehicle in which the active Spermatozoa are suspended.

Fig. 13.



This figure represents the several stages of evolution of the Spermatozoa in the common creeper (*Certhia familiaris*), magnified about a thousand diameters. *l*, an adult Spermatozoon, taken from the orifice of the vas deferens; *a*, *b*, *c*, seminal granules, which are probably nothing more than altered epithelial cells; *d*, *e*, *f*, cysts or vesicles enclosing one or more round granular globules; *g*, a similar cyst containing, besides the two globules, a finely-granular mass, in which the Spermatozoa may be seen to form; *h*, the cyst, still containing finely-granular matter, has assumed an oval form, and the bundle of spermatic animalcules, increased in size, lies bent up within it; *i*, a cyst still more developed; the involucrum, pear-shaped, covers the bundle of animalcules where their spiral extremities lie; *k*, a cyst arrived at maturity, still covered by the involucrum. (After Wagner.)

Until very recently these minute bodies were regarded as individual animated creatures; and many authors have fancied that several forms of them at least presented a somewhat complicated organization, such as an intestine, gastric sacculi, and even generative organs[1]. More recent researches have, however, satisfactorily proved that they are in all cases composed of a uniform homogeneous substance of a yellowish colour, in which no traces of complexity of structure are discernible. Their movements, however, are in most cases exceedingly vivacious; and were it not for the now well-ascertained fact that many other constituent elementary tissues, both animal and vegetable, exhibit equal activity even long after their separation from the organisms to which they belong, we might still be tempted to assign to them a much higher position in the scale of vitality than that to which they are really entitled. The motions of the Spermatozoids are, however, evidently only comparable to the automatic movements of cilia, and the relationship which they bear another manner, which is the ordinary mode of their reproduction, and forms a very interesting portion of their history*. At certain seasons of the year, if a living sponge be cut to pieces, the channels in its interior are found to have their walls studded with yellowish gelatinous granules, developed in the parenchymatous tissue; these granules are the germs or gemmules from which a future race will spring; they seem to be formed indifferently in all parts of the mass, sprouting, as it were, from the albuminous crust that coats the skeleton, without the appearance of any organs specially appropriated to their development. As they increase in size, they are found to project more and more into the canals ramifying through the sponge, and to be provided with an apparatus of locomotion of a description such as we shall frequently have occasion to mention. The gemmule assumes an ovoid form (fig. 10, B), and a large portion of its surface becomes covered with innumerable vibrating hairs, or *cilia*, as they are denominated; these are of inconceivable minuteness, yet individually capable of exercising rapid movements, whereby they produce currents in the surrounding fluid. As soon therefore as a gemmule is sufficiently mature, it becomes detached from the nidus where it was formed, and being whirled along by the issuing streams, is expelled through the fecal orifices of the parent, and escapes into the water around. Instead, however, of falling to the bottom, as so apparently helpless a particle of jelly might be expected to do, the ceaseless vibration of the cilia upon its surface propels it rapidly along, until, being removed to a considerable distance from its

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[1] *Vide* Leuwenhoeck, vol. iv. pp. 268, 284: Ehrenberg, Infusionsthierchen, p. 465: Valentin, Nov. Act. Acad. Leopold. vol. xix. p. 239.

to ciliated epithelium-cells is rendered abundantly manifest by the revelations of the microscope to modern observers[1]. From these researches it would appear that the origin of the Spermatozoa is invariably to be traced to nucleated cells, in the interior of which they are individually developed. These developing-cells, or vesicles, as they are termed, are found at certain seasons crowding the seminiferous tubes of the testes in immense numbers. Taken from the body after death they are seen to be perfectly transparent and filled with a fluid which on coagulating becomes somewhat granular. Most of these *developing-cells* (fig. 13, *a*, *b*, *c*) are found freely floating in the minute seminal canals, but frequently they are enclosed in another cell-like envelope, either singly (*d*) or in numbers of three, four, six, or seven in each; the existence, however, of a more considerable number (*e*, *f*) in one common cyst is unusual. Whether single or more numerous, however, it is in the developing-cells that the Spermatozoa are formed by a kind of endogenous growth, at first appearing like dim shadows lying amongst the contained granules, but gradually assuming a sharper outline as the body and, subsequently, the tail are perfected. The entire Spermatozoon at length becomes visible coiled up in the interior of the cell, which, when the development is completed, bursts and discharges its contents.

* Professor Grant.

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[1] *Vide* Von Siebold, in Müller's Archiv, 1836 and 1837: R. Wagner, Fragmente zur Physiologie der Zeugung; Beiträge zur Geschichte der Zeugung und Entwickelung, in den Abhandlung. der Königl. Bayerisch. Akad., Munich, 1837: Kölliker, Beiträge zur Kenntniss der Geschlechtsverhältnisse und Samenflüssigkeit wirbellosen Thiere, Berlin, 1841; Die Bildung der Samenfäden in Bläschen, Nuremberg, 1846.

original, it attaches itself to a proper object, and, losing the now useless locomotive cilia, it becomes fixed and motionless, and developes within its substance the skeleton peculiar to its species, exhibiting by degrees the form of the individual from which it sprung. It is curious to observe the remarkable exception which sponges exhibit to the usual phenomena witnessed in the reproduction of animals, the object of which is evident, as the result is admirable. The parent sponge, deprived of all power of movement, would obviously be incapable of dispersing to a distance the numerous progeny that it furnishes; they must inevitably have accumulated in the immediate vicinity of their place of birth, without the possibility of their distribution to other localities. The seeds of vegetables, sometimes winged and plumed for the purpose, are blown about by the winds, or transported by various agencies to distant places; but in the present instance, the still waters in which sponges grow would not have served to transport their progeny elsewhere, and germs so soft and delicate could hardly be removed by other creatures. Instead therefore of being helpless at their birth, the young sponges can, by means of their cilia, row themselves about at pleasure, and enjoy for a period powers of locomotion denied to their adult state.

(62.) Very widely distributed through the ocean, whether in tropical or extra-tropical climates, peculiar gelatinous bodies may be found floating upon the surface of the water; indeed they are occasionally among the most constant of all the various products of the towing-net. The THALASSICOLLA[*] (for so these simple organisms are designated by Professor Huxley[†]) is found in transparent, colourless, gelatinous masses of very various form—elliptically elongated, hourglass-shaped, contracted in several places, or spherical, varying in size from an inch in length downwards,—showing no evidence of contractility nor any power of locomotion, but floating passively on the surface of the water. Of such bodies there appear to be two very distinct kinds. In one, the mass consists of a thick gelatinous crust containing a large cavity. The crust is structureless; but towards its inner surface minute spherical, spheroidal, or oval bodies are imbedded (fig. 14, 2), each of which appears to be a cell with a thin but dense membrane, and containing a clear fatty-looking nucleus surrounded by granules,—the whole substance, in fact, resembling an animal *Palmella*. Very commonly the central part of each mass, instead of containing a single large cavity, consists of an aggregation of clear, closely appressed spaces resembling vacuoles (fig. 14, 3); and frequently each cell is surrounded by a zone of peculiar crystals, somewhat like the stellate spicula of a sponge, consisting of short cylinders, from each end of which three or four conical spines radiate, each of these again bearing small lateral processes (fig. 14, 4 & 5). Frequently the connecting substance in which the cells are imbedded appears to be quite structureless; but in some specimens delicate, branching, minutely granular fibrils may be seen radiating from each cell into the connecting substance (fig. 14, 4).

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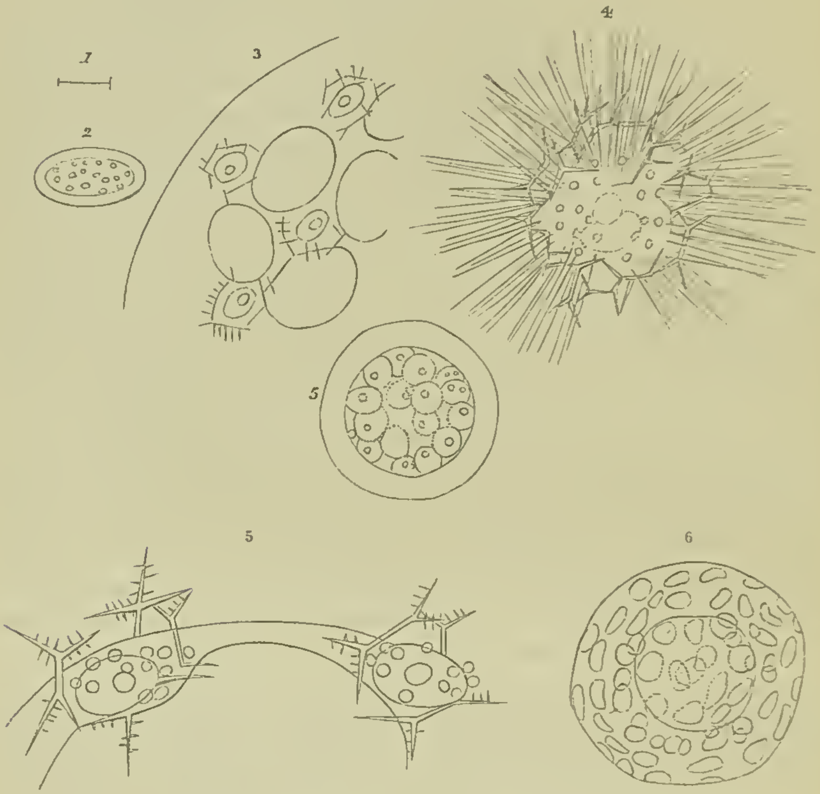
[*] *θάλασσα*, the sea; *κόλλα*, glue.

[†] *Vide* Ann. and Mag. of Nat. Hist. ser. 2. vol. viii. p. 433.

Fig. 14.



Structure of *Thalassicolla* (after Professor Huxley).

In the second form of *Thalassicolla*, the creature consists of a spherical mass of jelly, as large as the middle-sized specimens of the last variety, with an irregular blackish central mass. Enveloping this, and forming a zone about half the diameter of the sphere, are seen numerous clear spaces (vacuoles), and among these are scattered numerous yellow cells and a multitude of very dark granules. Delicate, flattened, branching fibrils radiate from the innermost layer, passing between the vacuoles; and in one specimen Professor Huxley observed these fibrils thickly beset with minute dark molecules which were in active motion, as if circulating along the fibrils, but without any definite direction.

CHAPTER III.

INFUSORIA*.

(63.) If we examine a drop of water taken from any pond or ditch in which vegetable or animal substances have been permitted to undergo incipient decay, with a microscope even of very limited power, we must soon perceive that it swarms with innumerable organisms, which are evidently endowed with life and exhibit considerable activity. From the circumstance of their extreme minuteness, these microscopic beings were designated by their first discoverers "*Animalcules*," to which appellation, from the fact of their generally making their appearance in vegetable infusions, the term "*Infusorial*" was very generally superadded by their earlier investigators. Progressive improvements in the structure of the microscope, however, soon made it apparent that the so-called Infusorial or Microscopic Animalcules embraced a vast variety of different forms of living beings possessed of little in common except their invisibility to ordinary observation: the larvæ and even the adult states of innumerable Insects, Crustaceans, Worms, and Zoophytes were all comprehended under a term so general; and even microscopic Algæ, Desmidieæ, and Diatomaceæ, now universally acknowledged to be members of the vegetable domain of Nature, were included in this chaotic assemblage—organisms widely dissimilar from each other both in their shape and structure.

It would be foreign to our present purpose to analyse the successive steps whereby something like order has at length been established in a scene of such apparently inextricable confusion, and how *pari passu* with the improvement of the microscope has been the rapid advancement of knowledge in connexion with these until so late a period unknown existences; suffice it to say that, in accordance with

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[*] *Vide* Müller, 1786: Ehrenberg, Infusionsthierchen, 1837: Dujardin, Hist. Nat. des Zoophytes: Pineau, Ann. Sc. Nat. 3^e sér. tomes iii. v. ix.: Stein, Wiegm. Archiv, 1849; id. Sieb. and Köl. Z. iii.; id. Die Infusionsthierchen, Leipzig, 1854: Peltier, l'Institut, 1836: Focke, Isis, 1836, and Physiolog. Studien: Kutorga, Naturgesch. d. Infusionsthierchen: Meyen, Müller's Archiv, 1839: Pritchard, Infus. Anim.: R. Jones, Ann. Nat. Hist. 1839: Werneck, Ber. d. Berl. Akad. 1841: Erdl, Müll. Archiv, 1841: Griffith, Ann. Nat. Hist. 1843, xii.: Siebold, Lehrbuch Vergl. Anat.: Cohn, Sieb. and Köl. Z. iii. 260: Kölliker, Sieb. and Köl. Z. i. 198: Claparède, Wiegm. Arch. Dec. 1854, translated in Ann. Nat. Hist. 2 ser. xv. 211: Schneider, ibid. p. 191, translated ibid. xiv. p. 322: Carter, Notes on the Infusoria of Bombay, Ann. Nat. Hist. for 1856 and 1857: A memoir by Dr. N. Lieberkuhn in Müller's Archiv for 1856, translated in Ann. Nat. Hist. for Oct. 1856.

the more refined characteristics now adopted in zoological classification, Crustaceans and Insects, as well as the larvæ of Annelidans, Zoophytes, and Echinoderms, have been successively withdrawn from the group and located in their appropriate stations, while innumerable zoospores and embryonic plants, together with the Desmidiaceæ and the Diatomaceæ generally, are by common consent conceded to the botanical series of Creation*. Still, as it would appear, the zoologist is reluctant to dissever forms of life which habit has accustomed the microscopical observer to associate with each other; and even M. Dujardin, one of the latest and most unprejudiced writers upon the history of these

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* It is by no means an easy task to indicate the boundary-line which separates the animal from the vegetable kingdom. The most important difference, that the vegetable cell-membrane contains no azote, while the animal cell-membrane does, cannot be applied in doubtful cases, the tenuity of the membrane not allowing of the investigation. That animals possess the power of locomotion, but plants not, is incorrect as applied generally, and is still less applicable here, because many unicellular Algæ exhibit motion, frequently very energetic motion (when swarming), whilst the ova of multicellular Algæ are quiescent. The unicellular Algæ differ from the Infusoria in this, that their membrane and its appendages are not motile, and that consequently they have a rigid form, whilst the latter in some instances change their figure, and in others are furnished with motile cilia. The presence of starch is, further, not invariably decisive as to the vegetable nature of a cell. The ova of multicellular animals, the figure of which is rigid and unchangeable, may also be recognized as not belonging to the unicellular Algæ from their want of colouring matter, which is present in the latter.

We can scarcely expect Chemistry to decide what is animal and what plant. The non-nitrogenous cellulose, which at first sight appears to be an exclusive attribute of the vegetable, is also found pretty generally in the animal kingdom, as we learn from the researches of G. Schmidt on *Cynthia mammillaris*, and those of Kölliker and Löwig on a great number of the most various of the lower animals. Just as little does chlorophyll appear to be exclusively characteristic of the vegetable world, since the green granules and vesicles which occur imbedded in the parenchyma of *Hydra viridis*, of various *Turbellariæ* (*Hypostomum viride* and *Tryphoplana viridata*, Schm.), and of Infusoria (*Stentor polymorphus*, *Bursaria vernalis*, *Loxodes bursaria*, &c.), are probably closely allied to chlorophyll, if not identical with it. Erythrophyll also might be said to occur in the lower animals (for instance in *Leucophrys sanguinea* and *Astasia hæmatodes*), in which latter the red colour frequently passes into green, as does the erythrophyll of unicellular Algæ[1].

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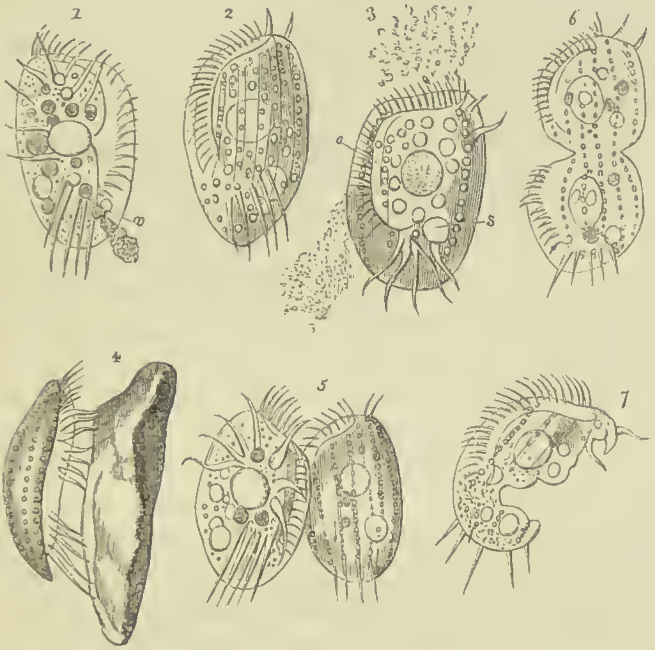
[1] The colouring matter of plants is distinguished by botanists into *Chlorophyll*, *Erythrophyll*, *Phycochrom*, and *Diatomin*. The *Chlorophyll* is of a grass- or yellow-green colour, little or not at all affected by diluted acids and alkalies, and frequently turns brown upon the death of the plant. The *Erythrophyll* presents a red or purple colour, not changed by diluted acids, but becoming green on the addition of alkalies, and also most usually after death. The *Phycochrom* is verdigris-green or orange, changed into orange by the action of diluted acid, and into a brown-yellow by that of alkalies. The *Diatomin* is brownish yellow, not altered by diluted alkalies, but changed into verdigris-green by diluted hydrochloric acid, and usually after death. *Vide* Nägeli, Gattungen einzelliger Algen, physiologisch und systematisch bearbeitet: Zürich, 1849.

living atoms, includes under the term Infusoria, animalcules essentially remote both in their general characters and intimate organization.

(64.) The Infusoria, as characterized by M. Dujardin, are creatures which, when examined under the microscope, appear to be composed of a homogeneous, glutinous, diaphanous substance, and are either naked or partially enveloped in a more or less resisting integument. Their usual shape is rounded or ovoid. Some (and these are the forms most commonly met with, which at once arrest the eye of the micrographer) are provided with vibratile cilia, which, either used occasionally or continually in motion, serve the purpose of innumerable oars for the movements of the animalcule, or in some cases merely act as agents in supplying provisions to the little creature's mouth; others instead of vibratile cilia are furnished with only one or two or sometimes several extremely slender filaments, which they agitate with an undulatory movement, and are thus enabled to advance through the fluid wherein they swim; whilst others, provided with neither cilia nor flagelliform filaments, move about by simple contractions and extensions of the general substance of their bodies.

Fig. 15.



Euplotes Charon (Ehr.). 1. Animalcule seen from below, exhibiting the locomotive apparatus composed of *uncini*, *styli*, and *setæ*: *v*. the anal aperture. 2. Dorsal aspect of the same, covered with a delicate shell. 3. A similar view showing the ciliary currents, the position of the mouth o', the nucleus *t*, and the contractile vesicle *s*. 4. Side view representing the animalcule creeping upon the surface of a fragment. 5. Two animalcules conjoined by their mouths; in one, the ventral, in the other the dorsal aspect is uppermost. 6. A specimen exhibiting the process of reproduction by transverse fissure. 7. Destruction of the animalcule by diffluence of the soft parts.

(65.) The forms last mentioned, as the reader will at once perceive, naturally arrange themselves among the Rhizopoda, described in the last chapter. Those provided with flagelliform filaments which they employ as instruments of locomotion, such as the *Monadina*, *Cryptomonadina*, *Pandorina*, *Chlamidomonas*, and *Volvox* of Ehrenberg, are now unhesitatingly admitted to belong to the vegetable kingdom; so that the ciliated forms alone are left to the zoologist, and offer themselves for our study upon the present occasion.

(66.) The movements of the CILIATED INFUSORIA, when seen under the microscope, are frequently exceedingly vivacious; they swim about with great activity, avoiding each other as they pass in their rapid dance, and evidently directing their motions with wonderful precision and accuracy. Our first inquiry therefore must be concerning the organs of locomotion which they possess. These are of various kinds, and are arranged differently in different species. Some are provided with *styli*, or articulated, stiff, bristle-like organs, which are moveable, and perform in some measure the office of feet, and with *uncini*, or little hooks, serving for attachment to foreign bodies; these are seen in *Euplotes Charon* (fig. 15, 4).

(67.) But the most important locomotive agents are the cilia*, with which these Infusoria are invariably furnished. On attentive examination, their body will be found to be entirely covered with minute vibrating hairs, or at least furnished with such appendages on some part of its surface (fig. 15, 1, 2, 3). The existence of these cilia is readily detected by a practised eye, even when using glasses of no very great magnifying power, by the peculiar tremulous movement which they excite in the surrounding fluid, somewhat resembling the oscillations of the atmosphere in the neighbourhood of a heated surface; but on applying higher magnifiers, especially if the animalcule is in a languid state, the motion is seen to be produced by the action of the delicate filaments of which we are speaking. Although extremely difficult accurately to define the motion of the individual cilia, it is obvious that the combination of their movements gives rise to currents in the water, serving a variety of purposes in the economy of these minute beings.

(68.) The cilia, as has been already observed, are sometimes dispersed over the whole body, either arranged in parallel rows or scattered irregularly; they are, however, most frequently only met with in the neighbourhood of the mouth, in which position they are always most evident: here they produce, by their vibration, currents in the surrounding fluid, which converge to the oral aperture, and bring to the mouth smaller animalcules, or particles of vegetable matter, which may be floating in the neighbourhood, thus ensuring an abundant supply of food, which, without such assistance, it would be almost impossible for these little creatures to obtain.

(69.) With the locomotive organs of these minute beings must likewise be classed the delicate and highly irritable stems of the *Vorticellæ*

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* *Cilium*, an eyelash.

(fig. 21), which on the slightest touch shrink into spiral folds, and again straighten themselves to their full extent. The agent by which this contraction is effected is a delicate spiral thread contained in the interior of the flexible stem, regarded by Ehrenberg as a muscular filament; its muscular nature is, however, doubted by Dujardin, who regards this as being one of the most inscrutable points connected with their economy. That a central canal exists in the retractile stem is generally admitted, and likewise that it contains a fleshy substance less transparent than the rest of the tube; but, according to M. Dujardin's observations, it is the diaphanous substance around this central cord that contracts, and as it forms a band one border of which is much thicker than the other, the more powerful action of the thicker portion gives that helical curvature to the stem which forms so remarkable a feature in its movements.

(70). When certain species of Infusoria (e.g. *Bursaria leucas*) are examined under a sufficiently high power, minute fusiform corpuscles may be detected thickly imbedded in the integument. These bodies are perfectly colourless and transparent; they are about $\frac{1}{2500}$th of an inch long, and may easily, even without any manipulation, be witnessed at the margin, where they are seen to be arranged perpendicular to the outline of the animalcule, while on the surface turned towards the observer their extreme transparency and want of colour render them invisible against the opake background, and it becomes necessary to crush the animalcule beneath the covering-glass, so as to press out the green globules which it contains, in order to bring the fusiform bodies into view. To these bodies it has been proposed to give the name of *trichocysts.*

As long as the animalcule continues free from annoyance, the trichocysts undergo no change; but when subjected to external irritation, as occurs during the drying away of the surrounding water, or the application of acetic acid or other chemical irritant, or the too forcible action of the compressor, they become suddenly transformed into long filaments, which are projected from all parts of the surface of the animalcule; these filaments have been mistaken for cilia by Cohn and Stein. The rapidity with which their evolution is effected, joined with the great minuteness and transparency of the object, renders it extremely difficult to follow it.

(71.) It is not difficult, by rapidly crushing the animalcule, to force out some of these organs in an unchanged state. If the eye be now fixed on one of the isolated trichocysts, it will most probably be seen, after the lapse of a few seconds, to become all at once changed (with a peculiar jerk, as if by a sudden release from some previous state of tension) into a little spherical body. In this condition it will probably remain for two or three seconds longer, and then a spiral filament will become rapidly evolved from the sphere, apparently by the rupture of a membrane that had previously confined it, the filament unrolling itself so quickly that the eye can scarcely follow it, until it ultimately lies straight and rigid on the field of the microscope, looking like a very fine and long acicular crystal.

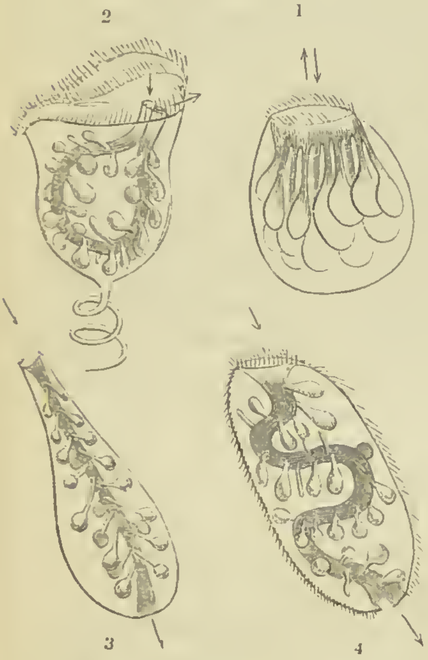
(72.) This remarkable filament, when completely evolved, consists of two portions—a rigid spiculum-like portion, acutely pointed at one end, and continuous at the opposite end with the second portion, which is in the form of an excessively fine filiform appendage, less than half the length of the spiculum. This second portion is generally seen to be bent at an angle on the first, and is frequently more or less curved at the free end. The form of the evolved trichocysts is best observed in such as have floated away towards the margin of the drop of water and are there left dry by the evaporated fluid. In many of them the filiform appendage is not visible, and they then merely present the appearance of a simple, long, fusiform spiculum.

(73.) Few subjects have afforded a more fertile field for discussion than the internal organization of these almost invisible creatures; and even at the present moment many points of their economy are by no means satisfactorily elucidated. The remoteness of their structure from that of the higher animals, and a natural mistrust felt by recent observers in the capabilities of the instruments placed at their disposal, gave rise at first to doubts and hesitation, which no longer exist.

The digestive apparatus of the Infusoria was originally described by Ehrenberg as consisting of a number of internal sacculi, varying from four to two hundred in number in different species. These sacs were stated by that indefatigable microscopist to be readily distinguishable without any preparation, but capable of being rendered more conspicuous by feeding the animalcules with pure carmine or indigo, the coloured particles of which substances they eagerly swallow. In one large division, called ANENTERA, the sacculi or stomachs were said to arise by separate tubular pedicles from the mouth itself (fig. 16, 1): whilst in others (ENTERODELA) there was supposed to be a complete intestinal canal, terminated by a mouth and anus, to which the sacculi or stomachs, as they were called, are appended: sometimes the intestinal canal is stated by the same authority to form a circle in the body ANOPISTHIA, Ehrenb.), as in the *Vorticella* (fig. 16, 2); or else the mouth and anus are placed at opposite extremities of the body, through which the intestinal tube passes either in a straight course, or exhibiting several flexuous curves in its passage (ENANTIOTRETA and ALLOTRETA, Ehren.) (fig. 16, 3 and 4). When neither the mouth nor anus is terminal, such animalcules belong to the group denominated KATOTRETA by the same author.

(74.) However imposing, from their completeness, the views of Ehrenberg concerning the digestive system of the polygastria may be, and sanctioned as they have been by almost general consent, we cannot pass over a subject of so much importance without expressing ourselves as being far from admitting their accuracy, and we must say that our own observations upon the structure of the polygastria have led us to very different conclusions*.

Fig. 16.



(75.) The positions of the mouth and anal aperture we are well assured, by frequent examination, to be such as are indicated by the illustrious Professor of Berlin; but with regard to the tube named by him intestine†, and the stomachs appended thereto, our most patient and long-continued efforts have failed to detect the arrangement depicted in his drawings. In the first place, as regards the function of the sacculi, which he looks upon as the organs in which digestion is accomplished: in carnivorous animalcules, which devour other species, we might expect, were these the stomachs, that the prey would at once be conveyed into one or other of these cavities; yet, setting aside the difficulty which must manifestly occur in lodging large animalcules in these microscopic sacs, and having recourse to the result of actual experience, we have never in a single instance seen an animalcule, when swallowed, placed in such a position, but have repeatedly traced the prey into what seemed a cavity excavated in the general parenchyma of the body.

(76.) In the second place, the sacculi have no appearance of being pedunculated and consequently in a certain degree fixed in definite positions: we have just been for two hours carefully examining some beautiful specimens of *Paramecium Aurelia* (fig. 16, 4), an animalcule which, from its size, is peculiarly adapted to the investigation of these vesicles; and so far from their having any appearance of connexion with a central canal, as represented in the figure copied from Ehrenberg, they are in continual circulation, moving slowly upwards along one side of the body, and in the opposite direction down the other, continually changing their relative positions with each other.

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* Perhaps some of our readers may think the above strictures upon the opinions of Professor Ehrenberg, which appeared in the first edition of this work, and have been written upwards of twenty years, have now become rather antiquated. It is, however, the wish of the author to combine some account of the progressive advancement of our knowledge relative to interesting or disputed points of microscopical research with an exposition of the views generally adopted by physiologists of the present day; and as the above were the first arguments advanced against the then universally received opinions of the distinguished author of the 'Infusionsthierchen,' it has been deemed expedient to retain them in their original words. It may be proper to state that the microscope used in these and similar researches to which allusion will be made, is a compound achromatic, made by Ross, of London; and the powers employed, of $\frac{9}{10}$, $\frac{1}{2}$, $\frac{1}{4}$, and $\frac{1}{8}$ of an inch focus.

† Since the above was written, Professor Ehrenberg has been kind enough personally to exhibit to the author his preparations of the central tube in several species of animalcules. The author's views, however, relative to the nature of the so-called stomachs remain unchanged.

(77.) With respect to the central canal (fig. 16, 2, 3, 4), we have not in any instance been able to detect it, or even any portion of the tube seen in the figures, much less the branches represented as leading from it to the vesicles or stomachs, as they are called. Even the circumstances attending the prehension of food would lead us to imagine a different structure; witness, for example, the changes of form which *Enchelys pupa* undergoes when taking prey, as shown in Ehrenberg's figure, where it is represented in the act of devouring a large animalcule, almost equal to itself in bulk, and is seen to assume a perfectly different shape as it dilates its mouth to receive the victim, with which its whole body becomes gradually distended. Such a capability of taking in and digesting a prey so disproportionate would in itself go far to prove that the minute sacculi were not stomachs, as it evidently cannot be in one of these that digestion is accomplished.

(78.) Since the above was written, the views of Professor Ehrenberg relative to the organization of the nutritive organs of the so-called Polygastric Infusoria have been combated by many zealous observers both in this country and upon the Continent, and appear now to be universally abandoned. Mons. F. Dujardin* attributes the formation of the internal cells observable in the interior of these animalcules to the properties of a peculiar glutinous animal substance resembling living jelly, of which he supposes the lower organisms to be principally composed, and which he calls *sarcode*. This substance, according to the views of M. Dujardin, spontaneously produces in the interior of its mass *vacuoles*, or little spherical cavities, into which the surrounding water finds access, and conveys along with it the coloured particles, but having no regularity of arrangement.

(79.) According to the views of M. Dujardin, the phenomena attending the passage of aliment into the bodies of the so-called Polygastric Infusoria may be described as follows—as they occur in *Amphileptus*. In the interior of the body there are generally perceptible five or six *vacuoles* or cavities, distended with water, in which are contained monads and other substances swallowed as food. These vacuoles change their situation, advancing gradually towards the posterior extremity of the animalcule, where may be observed a vacuole or vesicle of larger size (and frequently irregular shape, its contour being lobulated), evidently formed by the union of several smaller vacuoles, which, having been successively brought into contact, have become fused together like bubbles of gas. This largo posterior vesicle becoming more and more distended, its walls become thinner, and at last it opens externally by a wide lateral fissure, discharging its contents and then contracting to a comparatively small size. If this process be that which generally takes place (as it is supposed to be by M. Dujardin), the excretory orifice will be constantly formed at that point where the internal vesicles (so-called stomachs) terminate their career after having passed through the glutinous interior of the animalcule; and in this case its position, although it is not the termination of an intestinal canal, may be sufficiently constant to afford a character of classification.

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* "Recherches sur les Organismes inférieures." Ann. des Sc. Nat. 1835.

(80.) The celebrated botanist, M. Meyen*, regards the true Infusoria as being vesicular beings, having their interior filled with a kind of mucous substance. The thickness of the walls of the body, according to this observer, is in many species such as to be easily appreciated, and contains a spiral structure, which is readily perceptible, and which, as he thinks, establishes a complete analogy between these creatures and vegetable cells. In the larger kinds of Infusoria a cylindrical canal (the œsophagus) passes obliquely through the integument, and becomes dilated inferiorly, when distended with nutritive matter, to the size of the coloured globules met with in the interior of the body. The inner surface of this œsophageal tube is lined with cilia, by the action of which alimentary substances are kept in movement until they acquire a spherical shape. When the pellet thus formed becomes as large as the size of the pharynx will allow, it is expelled therefrom, and pushed into the cavity of the animalcule; a second pellet then accumulates, if any solid particles are contained in the surrounding fluid, which being in like manner impelled into the general cavity of the body, pushes the preceding one (which is now surrounded with mucosity) before it, and so successive pellets are formed one after the other, with which the cavity of the body becomes filled, giving the appearance that induced Professor Ehrenberg to consider these little beings as furnished with numerous stomachs. If no solid particles exist in the fluid surrounding the animalcule, the pellets are less consistent, exhibiting the appearance observable in specimens living in colourless water, in which case they are made up of a small number of particles, and seem to be principally composed of mucosity. Sometimes (observes M. Meyen) two of the pellets so formed are, when forcibly pressed together by the contraction of the body of the animalcule, observed to coalesce and become united into one mass,—a circumstance in itself sufficient to prove that they are not enclosed in stomachal walls.

(81.) In order to witness the formation of the pellets above described, it is necessary to begin the examination of the animalcule immediately on placing it in coloured fluid, as the deglutition of the coloured particles is very rapid; frequently, in the course of half a minute the pellets may be seen to issue one after the other from the œsophagus, and to be gradually propelled along the internal wall of the cavity of the animalcule. In *Paramecium, Kerona,* and the *Vorticellæ,* each new pellet pushes the preceding one before it so that they mount up along the opposite wall and are returned down the other side, until, after having accumulated to some extent, they are expelled one after the other from the anal outlet.

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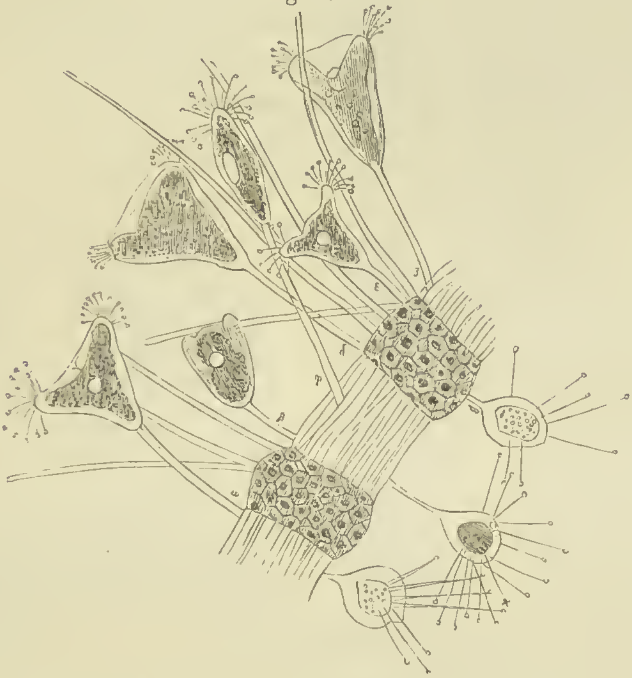
* "Quelques Observations sur les Org. digest. des Infus.," Ann. des Sc. Nat. 1839.

(82.) The number of pellets thus formed is frequently so considerable that they fill up the whole abdominal cavity, and so closely united together that they form a mass that revolves slowly upon itself, as may be seen in the *Vorticellæ.* This last kind of movement is the effect of the forcible expulsion of the newly-formed pellets from the gullet into the common cavity, of which fact M. Meyen assures us that he has had convincing proof. In other cases, when the number of pellets is small, they exhibit the kind of circulatory movement already spoken of, the cause of which is not so obvious.

(83.) The observations of Dr. Lachmann relative to the mode of feeding of the *Acineta* (fig. 17) throw considerable light upon this part of their economy. When an Infusorium touches the button-like dilated apex of the ray of an Acineta, it usually remains adhering to it; the apex of the ray becomes still more dilated, so as to form a sucking disk, and the ray becomes thicker and shorter; at the same time other rays make grasping movements, and endeavour to attach their extremities, which are dilated into sucking disks, to the captured prey. If the latter does not soon succeed in making its escape by great exertions, by which the rays of the Acinetæ are often much disarranged and injured, the Acineta begins to suck out its contents. Each ray is a sucking proboscis: and it may soon be seen that a current of chyme-particles runs from the alimentary cavity of the captured Infusorium into the body of the Acineta, through the axis of the rays, which, after seizing the prey, have become shortened and thickened. In the body of the Acineta, the chyme-particles still run at first in a single row, but afterwards they collect in a drop, which soon becomes amalgamated with other drops derived from other suckers. When a considerable quantity of the chyme of the captured animal has passed over into the Acineta, a remarkable change gradually takes place in its appearance: if it was previously pale, nearly transparent, and only very finely granulated, larger, dark globules, resembling fat-drops, now make their appearance here and there, and these soon increase, so that the body acquires a granular aspect and becomes opake. The globules or drops which thus make their appearance can only be formed in the body of the Acineta, as they are far larger than the chyme-particles which are seen flowing through the sucker. The animal whose contents are thus sucked out gradually collapses and dies; many become liquefied when only a little of the chyme is extracted from them, others still live for a long time; in large animalcules, such as *Stylonychia mytilus*, *Paramecium aurelia*, &c., the sucking often continues for several hours.

Fig. 17.



Acineta tuberosa (Ehr.), attached to a stalk of *Ceramium diaphanum*. The specimens marked α and ε are fully expanded; γ, side view of ditto; in δ the tentacula are seen in a partially, and in β in a fully contracted state. The three figures upon the opposite side of the stem of *Ceramium* represent *Acineta mysticina*.

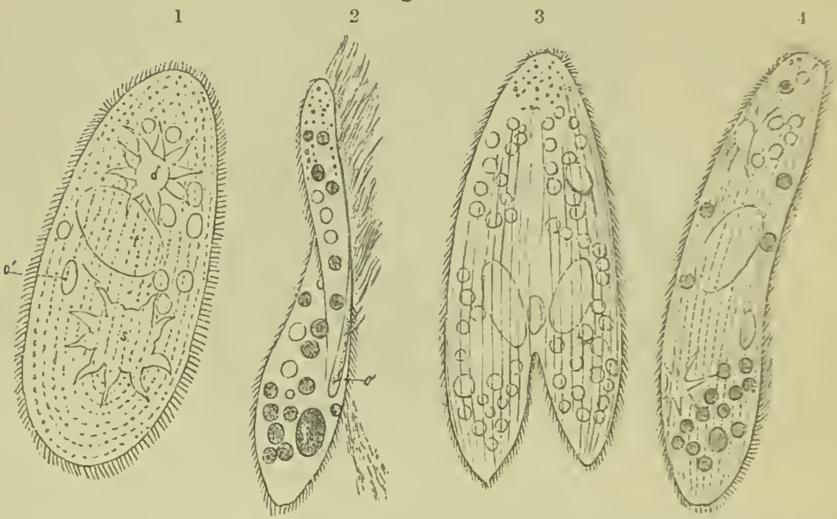
(84.) A number of roundish corpuscles, sometimes coloured, sometimes colourless, are generally found to occur diffused through the parenchyma of many Infusoria, which were considered by Ehrenberg as ova or spawn. The actual production of young from these corpuscles has, however, never yet been observed; and they are now believed to be nothing more than chyme-globules, which make their appearance after the digestion of food, as in the instance of the Acineta above-mentioned.

(85.) A coloured gastric juice has been described by Ehrenberg as existing in the gastric cavities of some Infusoria. The colour has, however, been accounted for by Siebold as produced by refraction and the presence of aggregations of pigment-granules. According to Professor Henfrey the reddish-violet colour is real, and arises from the presence of solution of the chlorophyll of certain *Oscillatoriæ*.

(86.) Two other organs remain to be mentioned which are common to all the Ciliated Infusoria, namely tho "*contractile space*" and the "*nucleus*."

(87.) The contractile space (seminal vesicle according to Ehrenberg) is regarded by many recent authors, in accordance with Dujardin's example, as a cavity destitute of proper walls (vacuole), which is sometimes supposed to form the analogue of a heart, and sometimes that of an excretory or respiratory water-vascular system. In order to be able to judge of these views, it will be necessary to examine rather closely into the behaviour of this "contractile space;" and for this purpose those Infusoria in which processes or branches derived from it can be detected appear to be particularly worthy of attention.

Fig. 18.

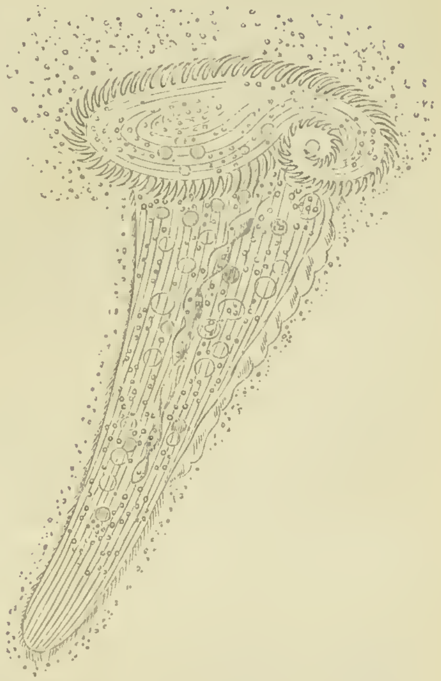


Paramecium aurelia (Ehr.), magnified 300 diameters. 1. The animalcule at rest, under slight compression: *o'*, the position of the mouth; *s*, *s*, contractile vesicles surrounded with radiating processes; *t*, nucleus. 2. Another specimen, placed in water coloured with indigo, showing the ciliary currents, the oral aperture, *o'*, and the coloured pellets in the interior of the body. 3. The same in process of longitudinal division, each segment containing a distinct nucleus. 4. A specimen swimming freely about after being fed with carmine; the mouth, nucleus, and star-like contractile vesicles are seen more in profile.

(88.) Radiating branches of the contractile spaces were first discovered by Ehrenberg in *Paramecium* and some other Infusoria. When the contractile space is fully expanded, the rays can only be observed as fine lines, or, when the light is not good, are entirely imperceptible. On the sudden contraction of the space, however, they instantly swell into pyriform cavities placed close to the position of the contractile organ which has disappeared. During the slow reappearance of the contractile space, the rays gradually decrease, and they in turn have almost disappeared or become reduced to fine lines when the vesicle has attained its full extension. These rays, as well as the contractile spaces, lie, as in all Infusoria, close under the skin ("cuticula" of Cohn), in the parenchyma of the body ("cortical layer" of Cohn).

(89.) The processes of the contractile space are seen with remarkable clearness in the large *Stentor polymorphus*, in which a very considerable portion of a vascular system may be recognized. The contractile space lies a little to the left of the œsophagus, near the plane of the ciliary disk; from it a longitudinal vessel runs to the posterior extremity of the animal, and an annular vessel round the ciliary disk, close under its series of cilia. Both these are visible even during the expansion of the contractile vesicle, but swell up suddenly during its contraction, like the rays of *Paramecium* above described; and then the longitudinal vessel usually exhibits considerable dilatations, which, when superficially examined, might easily be taken for independent disunited cavities (vacuoles): the annular vessel exhibits a more uniform aspect; only two rounded dilatations make their appearance in it. Both vessels gradually decrease during the reappearance of the contractile vesicle, apparently without any contraction of their own.

Fig. 19.



Stentor Mülleri (Ehr.), magnified. It is represented in a half-contracted state, and placed in indigo-water, so as to show the ciliary currents.

It is therefore probable that in all the Infusoria possessed of a contractile space, it is the centre of a vascular system which does not merely consist of chasms formed in the parenchyma by its accidental separation. Another and more difficult question concerning its nature remains to be cleared up, namely whether the vessels and the contractile space possess proper walls—in other words, whether the contractile space is or is not a vesicle. The mode of its contraction, which differs from the other contractile phenomena of the parenchyma of the body, appears to speak decidedly in favour of its vesicular character, as do some other facts, such as the phenomenon presented by *Spirostomum ambiguum*, an animalcule in which the anus is situated at the hinder end of the animal, and close in front of it is the very large contractile space. When fully expanded, this space appears to be surrounded only by a thin membrane; but nevertheless pellets of excrement, often several at the same time on different sides of the vesicle, form projections which are nearly hemispherical both towards the vesicle and the outer surface of the body,—a circumstance which could not happen if it were not a vesicle with proper walls.

(90.) When examined with a good microscope, the Infusoria are found to be possessed of another organ of very mysterious character, which, in accordance with the prevailing notion of their analogy with animal or vegetable cells, has been named the *nucleus*, and which certainly, as we shall see hereafter, seems to play an important part in their economy, more especially in connexion with the propagation of these animalcules.

The nucleus is usually roundish or longish, or even (as in many *Vorticellinæ* and *Stentor*) much elongated and band-like. It is enveloped in a peculiar membrane, and generally presents a homogeneous or finely granular appearance. It appears constantly to enclose a cavity surrounded with very thick walls, and sometimes contains a smaller body, designated *nucleolus*, which, however, in certain species is situated external to the nucleus.

The nucleus, as a general rule, seems to be affixed to the walls of the animalcule, as it does not appear at all to participate in the rotatory movements observable in the interior of the body.

(91.) In most, if not all Infusoria, the whole surface of the body is capable of exuding a gelatinous matter. Some do this regularly; and the exuded material either retains its gelatinous consistence, or, hardening into a horny substance, forms a sheath or shell (*lorica*), into which the animalcule can contract itself more or less completely.

Another kind of exudation also occurs in a great many species, which leads to the formation of a case or cyst enclosing the animalcule that secretes it—the object of which appears to be the protection of the encysted animal from unfavourable circumstances in the surrounding water, and from death from desiccation. This process of encystation is sometimes connected with the reproductive function, as we shall see hereafter.

(92.) The reproduction of these animalcules is effected in various ways; and not unfrequently the same individual would appear to propagate by two or three different modes of increase.

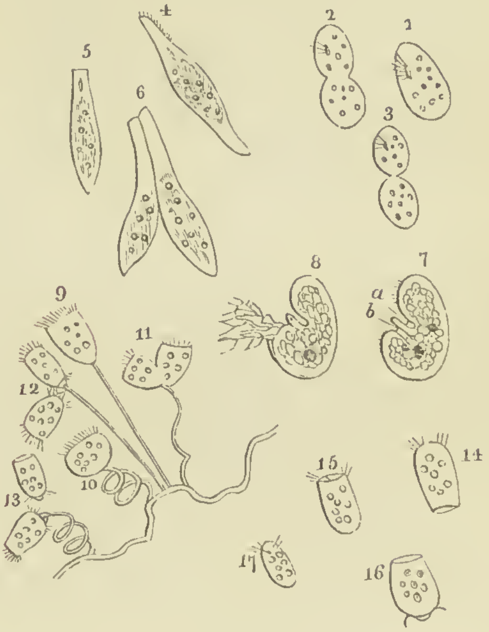
(93.) The first is by external gemmules or buds, which sprout like minute gelatinous tubercles from the surface of the body, and, gradually attaining the shape of their parent, develope the cilia characteristic of their species, and soon become independent beings, although they do not attain to their full growth until some time after their separation.

(94.) The most usual mode of propagation, however, is by spontaneous fissure, or division of the body of an adult animalcule into two or more portions, each of which is perfect in all its parts. This singular kind of generation, by which the old animalcule literally becomes converted into two or more young ones, is accomplished in various ways, which will require separate notice.

(95.) In the oval forms of the Infusoria, the line of separation generally divides the body transversely into two equal portions, by a process the different stages of which are represented in fig. 20, 1, 2, 3. The body of an animalcule about to divide in this manner becomes at first slightly elongated, and a line more transparent than the rest of its body is seen to cross its middle portion: a constriction becomes gradually apparent at each extremity of the line of division; this soon grows more decided, and at length the two parts are only united by a narrow isthmus (fig. 20, 3), which, getting thinner and thinner, allows a slight effort on the part of either of the now nearly distinct portions to tear itself from the other half and complete the separation.

(96.) In some elongated species (fig. 20, 4) the fissure is effected in a longitudinal direction, the separation gradually proceeding from the posterior to the anterior extremity of the body (fig. 20, 6); yet even in these the division is occasionally transverse, the newly-formed creature appearing truncated at one end (fig. 20, 5) for some time after the completion of the process.

Fig. 20.



(97.) The above mode of generation, as exhibited in *Vorticella*, a group of which is seen at fig. 20, 9, 10, 11, 12, 13, is very curious; and from the different forms assumed by the young during the progress of their development much confusion has occurred, each stage of growth having been described as the permanent appearance of a distinct species. This beautiful animalcule seems to be propagated in several ways. Sometimes this is effected by external gemmules, which appear like minute points, scarcely more than $\frac{1}{1000}$th of a line in diameter, upon the pedicles of the adult Convallariæ; these in time become pedunculated, and, although still very small, exhibit the cilia upon the margins of the delicate cups; in this state they were called by Schrank *Vorticellæ monadicæ* (fig. 21). The Vorticellæ generally, however, multiply by fissure, the bell-shaped cup at the extremity of their highly irritable pedicles separating longitudinally into two; but the progress of this division requires our particular notice, as the unpractised observer might be considerably puzzled on witnessing some of the phenomena attending it.

(98.) The adult animalcule (seen with its pedicle fully extended.

fig. 20, 9), when it is alarmed, shrinks by throwing its stem into spiral folds (10). In the latter figure, the bell or body of the animalcule is seen to have extended considerably in breadth, preparatory to its becoming divided into two distinct creatures. At 11, the commencement of its division is depicted,—the separation gradually extending from the base, or ciliated extremity, to the point where the body is attached to its stem. When the division has extended thus far (12), the newly-formed portion is seen with surprise to have become furnished with cilia at both ends, and when finally detached (13), only at the opposite extremity to that on which they originally existed; it then becomes freed from its pedicle, and thus losing the great characteristic of its species, swims about at large, exhibiting forms represented at 14, 15, 16, 17, all of which have been described as distinct species by different writers; at last it puts forth a new stem, and, assuming the adult form, becomes fixed by its pedicle to some foreign body.

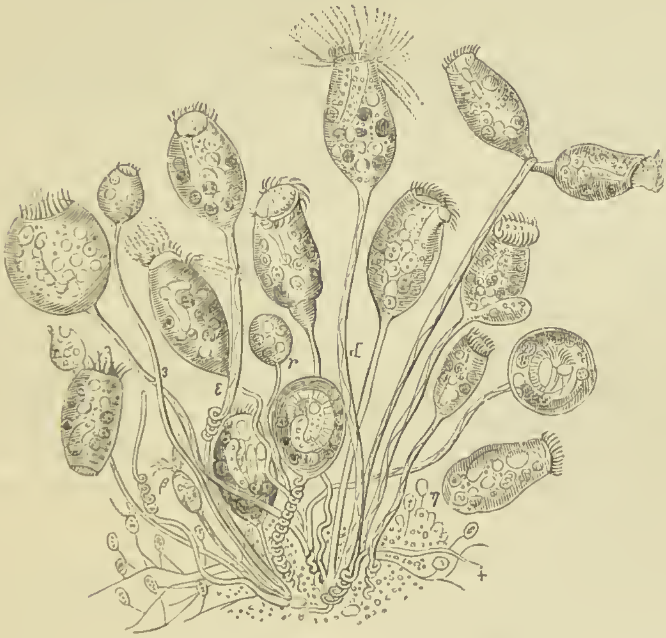
(99.) This fissiparous mode of reproduction is amazingly productive, and indeed far surpasses in fertility any other with which we are acquainted, not excepting the most prolific insects or even fishes. Thus a *Paramecium*, if well supplied with food, has been observed to divide every twenty-four hours, so that in a fortnight, allowing the product of each division to multiply at the same rate, 16,384 animalcules would be produced from the same stock; and in four weeks the astonishing number of 268,435,456 new beings would result from a continued repetition of the process: we therefore feel but little surprise that, with such powers of increase, these minute creatures soon become diffused in countless myriads through the waters adapted to their habits.

If the organization of these animalcules were as simple as it was supposed to be a few years ago, when they were thought to be mere specks of living jelly, imbibing nourishment at every point of their surface, which became diffused through all parts of the homogeneous texture of their bodies, their spontaneous division would be perfectly intelligible, and every step of the process easily understood; but, setting aside the conformation of their digestive apparatus, there are many circumstances attending the operation indicative of a power of developing new organs in the construction of every fresh individual, which must be looked upon as a very interesting feature in their history. Thus a new oral orifice, surrounded with cilia, must be formed upon the posterior segment of each divided animalcule. In *Nassula elegans* the curious dental apparatus, complex as its structure seems to be, must be developed upon the new part of the body preparatory to every separation; and accordingly a new mouth or dental cylinder is actually seen to sprout from the hinder half of the creature before its transverse fissure is complete.

(100.) Nearly all the Infusoria and Rhizopoda have in their interior a kind of nucleus, which is quite different in its compact texture from the parenchyma by which it is surrounded. The nucleus seems to play an essential part in the fissuration; for every time the animalcule divides either longitudinally or transversely, this organ, which is usually situated in the middle, divides also, so that each of the two new individuals has a nucleus. This nucleus, which is of a fine-granular aspect and dense structure, retains its form when the animalcule is pressed between two plates of glass and the other parts are spread out in various ways. By direct light its colour appears pale yellow.

(101.) A remarkable mode of reproduction, by *encystment*, observed first by Stein in different species of *Vorticella*, appears to exist commonly among all the animalcules of this class*. The individual about to become encysted contracts slightly, and closes its peristome; and around it there then appears a cloud-like sacculus formed by a viscid liquid, which is probably the result of a cutaneous secretion. In this liquid are developed granules, which, augmenting more and more in number, and adhering together, finally form a membrane, which becomes hard and resisting, although soft and flexible when first produced. This encystment appears to have a double purpose: first, to withdraw these very delicate animals from the destructive effects of drought and cold; and secondly, to allow them to undergo certain metamorphoses protected from all external influences.

Fig. 21.



Vorticella microstoma (Ehr.), showing different stages of the process of fissiparous reproduction. The basis to which the group is attached consists of a finely granular mucous mass.

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* M. J. d'Udekem, "On the Metamorphoses of the Vorticellæ," Ann. Nat. Hist. for July 1859.

The Vorticellian thus encased becomes attenuated and folded upon itself; the sarcodic substance appears to traverse its integument in all parts; from time to time it still contracts, but ultimately becomes completely dissolved, so that we find in its place merely a homogeneous sarcodic liquid, containing granules, together with the nucleus, which resists the general destruction. In the sarcode there takes place a process which may be in some measure compared with what occurs in the vitellus after the fecundation of an ovum. The granules becoming united together form groups, which soon divide and subdivide; at the same time an integument is formed upon the surface, which is contractile, covered with vibratile cilia, and closed at all points. The cyst now contains a new Infusorium, which may be compared with the *Opalinæ* or *Bursariæ* which are met with in the intestines of the Batrachians.

(102.) The next part of the process is the transformation of the ciliated Infusorium thus obtained into an *Acineta*. While the metamorphosed Vorticellian revolves in the interior of the cyst, it undergoes development, increases in size, and its whole surface becomes covered with folds: at length a moment arrives when the cyst, yielding to the pressure exerted in its interior, bursts; the ciliated Infusorium becomes free, and swims about with a rotatory movement, and is gradually developed into an *Acineta*. Fourthly, ciliated embryos make their appearance in the interior of the Acineta thus produced, apparently formed at the expense of the nucleus; the nucleus becomes totally converted into an embryo, and after the expulsion of the latter a new nucleus is formed, which in its turn becomes transformed into another embryo, and so on. Lastly, the embryos become fixed, and transformed into young *Vorticellæ*.

According to Stein, therefore, the *Vorticellæ* by this process of encysting are transformed into Acinetæ, and these again, by means of internal motile embryos which are emitted from them, change into Vorticellæ. But the reality of this metamorphosis has been disputed by several careful observers; nevertheless Professor Stein still retains his original views upon this subject*.

(103.) The encapsulation of *Kerona pustulata* is thus described by Mr. Carter:—"The first change that occurred was the absence of all crude aliment in the abdominal cavity; then a division of the nucleus into four parts, preparatory to its disappearing altogether. At the same time certain dark angular grains, which had been floating round with the sarcode of the abdominal cavity, became congregated in the posterior extremity. The *Kerona* now became shortened, its cilia disappeared, and finally it passed into a rounded-oval ball. This, after a certain time, resolved itself into an obtuse-elliptical capsule enclosing a spherical cell with a separate mass of dark angular grains. The capsule was laminated and ragged on the outside, and defined by a clear line internally, while the spherical cell contained all the vital remains of the Kerona, together with the contracting vesicle, but exclusive of the 'dark angular grains,' which, adhering more or less together, were still enclosed within the capsule. At this time the spherical cell was rotating, probably from the presence of cilia upon its surface, and the contracting vesicle active; but subsequently the granular mucus of which it was composed became transformed into a number of uniform, round, refractive, oil-looking bodies, and the contracting vesicle disappeared. After the lapse of nearly a month, the contents of the spherical cysts again became active, and had assumed definite forms, rotating rapidly in their cells, sometimes one way, sometimes the other, attended by intervals of rest; with many also a lifeless portion was present, which was forced round equally fast with the living one." Mr. Carter, however, was not fortunate enough to witness the actual escape of the enclosed animalcules.

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* *Vide* an elaborate paper by Dr. H. Cienkowski, in the 'Bulletin de la Classe Physico-Mathématique de l'Acad. Imp. des Sciences de St. Pétersbourg' for January 1855.

(104.) The encapsulation of *Plœsconia Charon*, likewise witnessed by Mr. Carter, presented analogous phenomena. "The Plœsconiæ had not appeared twenty-four hours when they began to assume a globular form by becoming shorter and shorter, and at the same time secreting an albuminous substance around them, within which the legs and cilia were gradually withdrawn, and a spherical capsule was thus formed, which adhered to the watch-glass. All trace of the Plœsconiæ now became lost, with the exception of the refractive globules in the abdominal cavity; and the contracting vesicle, although active at first, soon disappeared. In this passive state of existence the Plœsconiæ continued for two days, when the contracting vesicle again began to resume its functions, and the included animalcule, detaching itself from its capsule, began to rotate gradually. Cilia next presented themselves, the rotatory motion becamo accelerated, the distension of the contracting vesicle increased, until at last the capsule burst, and a portion of the cilia of the Plœsconia was at the same time protruded. A few minutes of rest now succeeded; and the cilia having been withdrawn, the rotatory motion was again resumed, while the distension of the contracting vesicle also going on, at last became so great as to force a portion of the body of the encysted Plœsconia through tho rent, when an interval of rest followed. Tho portion of the body was then withdrawn, and the same process repeated several times, until at length the Plœsconia obtained its exit. It was now almost spherical in shape, from the enormous distension of the contractile vesicle, behind which appeared numerous globules, and at the circumference the legs and cilia. In this state it continued stationary for some minutes, until the distensions of the contracting vesicle, evidently increased for the bursting of the capsule, were gradually reduced to their natural limits, when the different parts of the Plœsconia regained their respective positions, and the animalcule at last assumed its original form and bounded off in search of food."

(105.) The discovery of the propagation of the Infusoria by means of embryos or internal germs has opened a new field of research in the history of the development of these animalcules. From the researches of M. Balbiani *, it would appear that, besides the truly agamic modes of reproduction, namely, by spontaneous division and gemmiparity, there exists a process by which the young are formed in the interior of the parent, which gives them birth by the agency of distinct sexual apparatus. Stein was one of the first to call attention to the part played by the nucleus in the process of reproduction; but he thought that the germs were developed on the surface of this body by a species of gemmation which would assimilate them rather to bulbilli, or caducous buds, than to embryos originating from fertile ova. They would seem, however, to be really produced by an act of sexual generation. We will describe the phenomena witnessed by M. Balbiani in the common green Paramecium (*Paramecium Bursaria*, Focke; *Loxodes Bursaria*, Ehrenb.), as an illustration of what occurs in a great variety of other forms.

In this species, as probably in all Infusoria, there exists a nucleus, which is here accompanied by a small lenticular body, usually lodged in an excavation of the nucleus near one of its extremities, and generally described under the improper name of "nucleolus."

For several generations the Paramecia multiply by spontaneous scission, each of the two new individuals obtaining half of the primitive nucleus; but under the influence of conditions of which we are still ignorant, the animalcule is propagated in a very different manner. When the period arrives at which the Paramecia are to propagate with concourse of the sexes, they may be seen assembling upon certain parts of the vessel in which they are contained, either towards the bottom or on the walls. Soon they are found coupled in pairs, adherent laterally, and as it were locked together, with the similar extremities turned in the same direction, and their two mouths closely applied to each other. In this state the two conjugated individuals continue moving with agility in the liquid, and turning constantly round their axis. There is nothing before this copulation to indicate the considerable changes that are about to take place in the nucleus and the nucleolus which accompanies it. It is during the copulation itself (of which the duration is prolonged for five or six days or more) that their transformation into a sexual reproductive apparatus takes place.

(106.) At the end of this time the nucleolus has undergone a considerable increase in size, and has become converted into a sort of capsule of an oval form, the surface of which presents longitudinal and parallel lines or streaks. Nearly always it soon divides, in the direction of its greater axis, into two or more, frequently into four parts, which continue increasing, independently of each other, in a very irregular manner, and form so many secondary sacs or capsules. At a period which is still nearer that of division, these latter appear to be composed of an extremely fine membrane enveloping a number of small curved bacilla extending from one extremity of the sac to the other, inflated towards the middle, narrowed towards the extremities. It is these which, when seen through the enveloping membrane, give the capsule the striated appearance which is characteristic of it. It also contains a perfectly colourless and homogeneous fluid.

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* "On the existence of a Sexual Reproduction in Infusoria," Comptes Rendus, 29th March, 1858, p. 628.

At the same time, the nucleus has also changed its form and aspect; it has become rounded and widened; its substance has become softer, lost its refractive power; and towards the margins it presents notches which, penetrating more and more deeply into its mass, isolate one or more fragments, in which a sufficient magnifying power enables us to see a certain number of small transparent spheres with an obscure central point. In other cases the nucleus while still almost entire presents this aspect, and then appears as if stuffed with these little rounded bodies, the analogy of which to ovules cannot be doubted in the least. The evolution of the nucleus and nucleolus being identical, and progressing at the same rate in the two coupled individuals, it follows, if we regard the former as an ovary and the second as a testicle or seminal capsule, not only that each of them possesses the attributes of both sexes, but that they fecundate each other.

As regards this fecundation itself, everything seems to prove that it takes place by means of an exchange made by the two coupled individuals of one or more of their seminal capsules, which pass through the apertures of their mouths, closely applied to each other, from the body of one Paramecium into that of the other; for very often, although we may not be able to perceive this passage itself, we may detect the moment when one of the capsules already engaged in one of the mouths is on the point of clearing this aperture.

(107.) Each capsule after its transmission continues to increase in size in the body of the individual which has received it—frequently attaining a volume greater than that of the nucleus itself; but there is never more than one that arrives at maturity at the same time. When, having arrived at this state, it is examined after being pressed out of the body of the animalcule to free it from the granulations which mask it more or less while there, it appears under the form of a large ovoid body, the surface of which presents a multitude of parallel striæ directed longitudinally, due to the arrangement of the corpuscles contained in the interior. Compression, carried so far as to cause its rupture, shows it distinctly to be formed by a membrane of extreme tenuity containing an immense number of minute fusiform corpuscles, the extremities of which are imperceptible on account of their extreme fineness. As soon as they are free, these little bodies exhibit a vacillatory and translatory movement, which soon causes their dispersion in the circumambient fluid. These are the spermatozoids of *Paramecium Bursaria.*

(108.) It is usually from the fifth to the sixth day following the copulation that the first germs are seen to make their appearance, in the form of small rounded bodies formed by a membrane which is rendered very evident by acetic acid, and containing a greyish, pale, homogeneous or almost imperceptibly granular matter, in which neither nucleus nor contractile vesicle is yet to be distinguished: these organs do not appear till afterwards. Stein and F. Cohn have shown that these embryos quit the body of their parent under the form of *Acinetæ,* furnished with knobbed tentacles (true suckers, by means of which they remain for some time still adherent to the mother, deriving their nourishment from her substance); but their investigations did not reveal to them the ultimate fate of these young animalcules. M. Balbiani was able to follow them for a considerable time after they had detached themselves from the parent animalcule, and convinced himself that, after losing their suckers, becoming clothed with vibratile cilia, and obtaining a mouth, which first shows itself in the form of a longitudinal furrow, they definitely acquired the form of the mother, becoming filled in the same way with the green granulations characteristic of this Paramecium, without undergoing any more important metamorphoses.

M. Balbiani* did not succeed in witnessing the *deposition* of the ova, but he thinks it very probable that they escape by the anus or by some neighbouring aperture. In *Stylonychia* he observed them to collect in the posterior part of the body and diminish gradually in number from the first or second day after copulation, at which period a round pale body begins to make its appearance in the centre of the animalcule, which becomes constricted in the middle and reconstitutes the double nucleus.

(109.) The Infusoria would seem to be destitute of copulatory organs. In most cases sexual intercourse is effected by simple juxtaposition of the mouths of the two animalcules. In the *Oxytrichina* the union is more intimate, and goes so far as to constitute a true soldering of the two individuals for more than two-thirds of the anterior part of their length. Any one who had not witnessed all the phases of this remarkable copulation would necessarily regard this state as a case of longitudinal division proceeding from behind forwards: but the concomitant changes of the internal organs cannot leave the least doubt as to the signification of this act.

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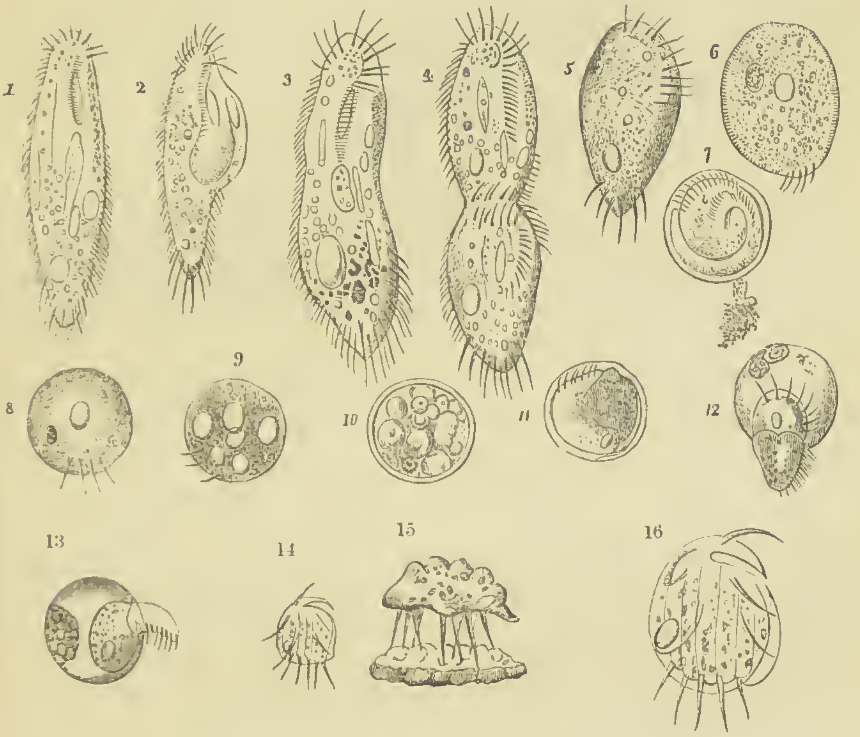
* "On the Generative Organs of the Infusoria," Ann. Nat. Hist. ser. 3. vol. ii. p. 443.

(110.) The remarkable history of *Trichoda Lynceus* has been studied by M. Jules Haime*. This animalcule would appear to commence its existence under the aspect of an *Oxytricha* (Ehrenberg) (fig. 22,1,2), in which condition it undergoes multiplication by transverse fissure in the usual manner (3, 4). The halves resulting from this division then assume a globular form, lose the greater part of their locomotive apparatus, and become encysted (5, 6). The contents of the cyst next separate from their envelope, leaving a space on one side, in which ciliary movement can be distinguished (7). This space spreads all round ; granular matter is expelled from the cyst, whereby its form becomes altered (8), and the distinction between the newly formed animalcule to which the cilia belong and the remains of the original creature becomes more and more apparent (9, 10, 11), until at last the former escapes through the

Fig. 22.



Metamorphoses of *Trichoda Lynceus*. 1. Larval condition (*Oxytricha*), seen from below. 2. The same, after swallowing another animalcule. 3. A very large specimen just about to undergo fission. 4. The same, showing the fissiparous process in a more advanced stage. 5. One of the products of such fission. 6. The same, having lost most of its cilia and assumed a spherical shape. 8. The same, now become completely motionless. 9. Appearance of the same after the lapse of fifteen days. 10. Later condition of the same, showing the formation of a cyst. 7 & 11. After the expulsion of a considerable quantity of exuvial matter, a ciliated animalcule appears in the interior of the cyst. 12 & 13. The included animalcule escapes from its encystment and at length assumes the form of an *Aspidiscus*, represented at 14. 15. The complete animalcule walking by means of its setæ. 16. Inferior aspect of the same when at rest.—All the figures are magnified 355 diameters, except the two last, which are shown under a magnifying power of 760 diameters.

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* Ann. des Sc. Nat. sér. 3. t. xix. p. 109.

walls of the cyst (12, 13, 14, 15, 16) and soon developes itself into an *Aspidiscus.* How the Aspidiscus returns to the Oxytricha-form is still a matter for speculation.

CHAPTER IV.

ANTHOZOA.

Zoophytes of old Authors. Phytozoa (Ehrenberg).

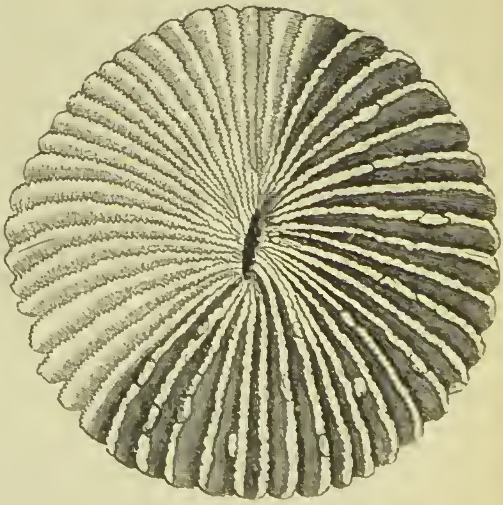
(111.) It is not surprising that many members of the extensive class upon a consideration of which we are now entering should have been regarded by the earlier naturalists as belonging to the vegetable kingdom, with which, in outward appearance at least, numerous species have many characters in common.

(112.) Fixed in large arborescent masses to the rocks of tropical seas, or, in our own climate, attached to shells or other submarine substances, they throw out their ramifications in a thousand beautiful plant-like forms. Incrusting the rocks at the bottom of the ocean with calcareous earth separated from the water which bathes them, they silently build up reefs and shoals, justly dreaded by the navigator and sometimes giving origin, as they rise to the surface of the sea, to islands which the lapse of ages clothes with luxuriant verdure and peoples with appropriate inhabitants.

(113.) Among the calcareous structures derived from the tropical seas, usually known by the general terms Madrepores, Corals, &c., and which, from the beauty of their structure, form the ornaments of our cabinets, few are more common than those denominated *Fungiæ* and *Meandrinæ*—animals belonging to the group *Madrephylliæa* of systematic zoologists.

(114.) These masses consist of thin plates or laminæ of calcareous matter (fig. 23), variously disposed in different species, but in the *Fungia agariciformis,* which we have selected as an example, radiating from a common centre, and forming a circular mass resembling a mushroom. When living in its native element, every part of the

Fig. 23.



Fungia agariciformis.

surface of this stony skeleton was incrusted with a layer of animal jelly, dipping down into the interstices of the plates, and covering the whole framework. In the figure, the darker portion indicates the living crust; whilst from the lighter parts it has been removed, to show the stony skeleton itself. There are no arms or moving parts adapted to the prehension of food, and no separation of organs for the performance of the vital functions; the thin membranous film apparently absorbs the materials of its support from the water of the ocean, and deposits within its substance the calcareous particles which it secretes, moulding them into the form peculiar to its skeleton, which it gradually enlarges as its own extent increases.

(115.) The gelatinous investment, however, gives certain dubious indications of vitality, and possesses a power of contraction so as to retire between the laminæ of its skeleton when roughly handled, and thus conceal itself from injury. Upon the surface of the soft crust are seen a number of vesicles (indicated in the figure), which have been regarded as rudimentary tentacula from the circumstance of their being able to contract and vary their dimensions; recent observations, however, lead to the belief that they are cavities filled with air, serving an important purpose in the economy of the creature—namely, that of preventing it from being turned upside down by the occasional agitation of the ocean. These air-vessels may therefore be looked upon as floats, which, rendering the upper surface more buoyant than the inferior, materially assist in preventing such an accident.

(116.) The reproduction of *Fungia* is effected by the development of sprouts or gemmæ which pullulate from the animal substance as buds issue from a plant, and remain for some time fixed to the parent by a species of foot-stalk, which sustains them until they have attained to a considerable size,—the young Fungiæ being upwards of an inch in diameter before they become detached. When mature, they separate from the top of the stony peduncle which hitherto supported them; and at this time the skeleton of the young Fungia, when divested of its fleshy part, shows a circular opening beneath, through which the radiating plates of the upper surface are visible. In a short time a deposit of calcareous matter takes place, which cicatrizes the opening, the marks of which, however, can be traced for a considerable period.

(117.) In the earliest period of its development, the foot-stalk by which the young is united to the parent, as well as its radiating disk, is entirely enveloped with the soft parts of the animal; but as the upper portion spreads, and assumes its characteristic form, the pedicle is left naked, and the gelatinous coating extends only to the line where the separation afterwards takes place.

(118.) It is generally supposed that the calcareous matter forming the skeleton of these madrepores is perfectly external to the living crust that secretes it, and accordingly is absolutely extra-vital and removed from the future influence of the animal. Such a supposition is, however, at variance with the facts above stated, and incompatible with many circumstances connected with the history of the lithophytous polyps. On trying to detach the soft envelope from the surface of the skeleton, the firmness of their adherence would render such a want of connexion improbable—they appear to be, as it were, incorporated with each other; and, besides, the separation of the Fungia from the peduncle whereby it was joined to the parent Fungia during its earlier growth necessarily supposes a power of removing the calcareous particles after their deposition. It is therefore demonstrable that the earthy matter secreted by the polyp is deposited in the tissue of its substance, and still remains, in a greater or less degree, subject to absorption and removal; of this, however, we shall have fuller evidence hereafter.

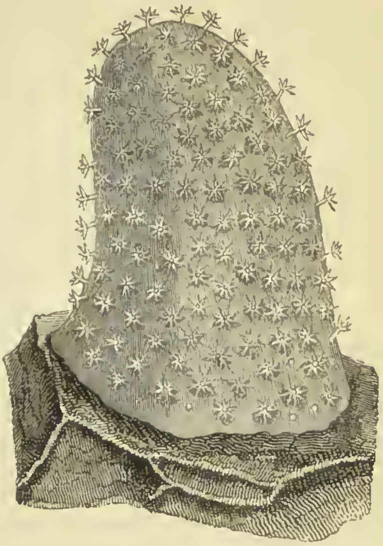
(119.) *Cortical compound* ANTHOZOA.—The compound polyps consist of a mass of gelatinous matter, which indicates, by its power of contraction upon the application of stimuli, a degree of sensation, and of a great number of polyps, or flower-like mouths, which spring from the surface of the common body, and are individually capable of seizing and digesting prey, the nutriment thus gained being appropriated to the nourishment of the general mass.

(120.) Although essentially similar in their habits, the compound polyps present various modifications of structure, which naturally causes them to be grouped in distinct families. Sometimes the central common mass is entirely soft and gelatinous, its surface being covered with minute cells in which the polyps are lodged: such are the *Alcyonidæ*. Sometimes the common body secretes large quantities of calcareous matter in the same manner as the *Fungia*, which, being deposited in its interior, forms arborescent masses, presenting upon their surface multitudes of cells, generally distinguishable after the removal of the outer crust, in each of which when alive a polyp was lodged: these form the family of *Madreporidæ*. The central axis is not unfrequently quite solid and smooth upon the surface, offering no cells for the lodgment of the polyps—being either composed of hard and dense calcareous substance, or else flexible and horny in its texture: such are the *Corallidæ*, or family of corals, properly so called. The internal central axis is moreover, in another family, composed of several pieces united together by the living crust that secretes them: and being free and unattached, such forms are probably able to change their position at pleasure: these constitute the family of *Pennatulidæ*, or swimming polyps. They are, however, all merely modifications of the same general type of structure, although differing in certain minor points of their organization, so as to render an examination of each form needful for our purpose.

(121.) ALCYONIDÆ.—This family includes several genera, known by the names of *Alcyonium*, *Lobularia*, *Cydonium*, &c., being characterized by having no solid axis developed in the interior of the common body. The *Cydonium Mülleri* (fig. 24) will give the reader a good idea of the general appearance of one of these compound animals. The central mass, or polypary, is entirely soft, being of a gelatinous, or, rather, subcartilaginous texture. Upon cutting into it, it is found to be intersected by tough fibrous bands, and not unfrequently contains calcareous spicula dispersed through its substance: no muscular fibre or nervous matter has ever been detected in its composition, and its interior is permeated by numerous wide canals variously disposed.

(122.) Few objects exhibit to the naturalist a more beautiful spectacle than the compound animals of which we are speaking. When found upon the shore contracted and deformed, it would be difficult to imagine that they were really organized beings, much less possessed of any elaborate conformation; yet on placing one of them in a tumbler of sea-water and watching it attentively, its true nature is gradually revealed: the central mass expands in all directions, exhibiting the cells upon its surface, from which in time the countless flower-like polyps are protruded, which, stretching out their arms in all directions, wait for the approach of prey. A scene like this naturally leads us to inquire concerning some points of physiology connected with their economy; and several questions obtrude themselves upon us, which, as they are applicable to the whole group of compound polyps, may be well discussed in this place.

Fig. 24.



Cydonium Mülleri.

(123.) That there is a community of nutrition—or, in other words, that food taken and digested by the individual polyps is appropriated to the support of the general body—is generally admitted; but is there a community of sensation, so as to render the entire mass one animal, capable of consentaneous movements? or is each polyp independent of the rest in its sensations and actions? Upon this there are different opinions,—some regarding the whole as a single animal, each part being in communication with the rest, and thus participating in the feelings and movements of the others, whilst some consider every polyp as a distinct creature, independent of the rest. The solution of this problem is a matter of some difficulty; but there are several facts which may in some measure enlighten us upon the subject. From the absolute want of nervous filaments which might bring into communication distant points of the body, we might, theoretically, deny the possibility of any combination of actions; and experiment teaches us that the assumption is correct.

(124.) If, when one of these animals is fully expanded, transparent, and soft, any point of its surface be rudely touched, the whole body does not immediately shrink, but only the point where the irritation was applied appears to feel the impression; this part shortly becomes more dense, opake, and a depression is seen gradually to appear. If the shock be severe, and extensively diffused over the body, the contraction slowly extends to the whole mass: the most violent local injury, indeed, seems to be totally unperceived at remote parts of the body; whilst a general shock, such as striking the vessel which contains the expanded polyp, produces a simultaneous contraction of the whole*. The polyps, however, exhibit much greater irritability than, and their movements, from their rapidity, form a striking contrast to the languid contractions of the central portion: but that they have a community of life appears improbable; they seem to act quite independently of each other: when one is touched, and suddenly retracts itself within its cell, it is true that those in the vicinity will likewise not unfrequently retire; but this circumstance may be accounted for by the sudden movement of their neighbour; for as the polyps are closely contiguous to each other, there is no cause for urging a community of substance to explain it†.

(125.) It has been observed by Milne-Edwards‡, in *Alcyonidium* (fig. 25)—a genus of Alcyonian zoophytes remarkable from the circumstance that its polypary, or common body, consists of two portions of very different consistence, the upper part or *trunk* (*c*) being quite soft and flexible, while the lower portion or *foot* (*b*), by which it is attached, is of a hard and solid texture,—that although under ordinary circumstances the movements of the individual polyps are quite independent of the rest, a simultaneous contraction of the whole may be excited by irritating the common trunk, and that to such an extent that, if the stimulation be excessive, the whole of the soft portion of the polypary is retracted into a coriaceous sheath afforded by the foot.

(126.) On making a longitudinal section of one of the expanded polyps (fig. 26, 1), the main features of its anatomy become at once recognizable. The alimentary canal (*c*) is seen to be a cylindriform cavity with membranous walls, occupying the axis of the upper portion of the body, and extending from the mouth (*b*) to about the middle of the free portion of the protruded polyp, where it terminates by a distinct orifice

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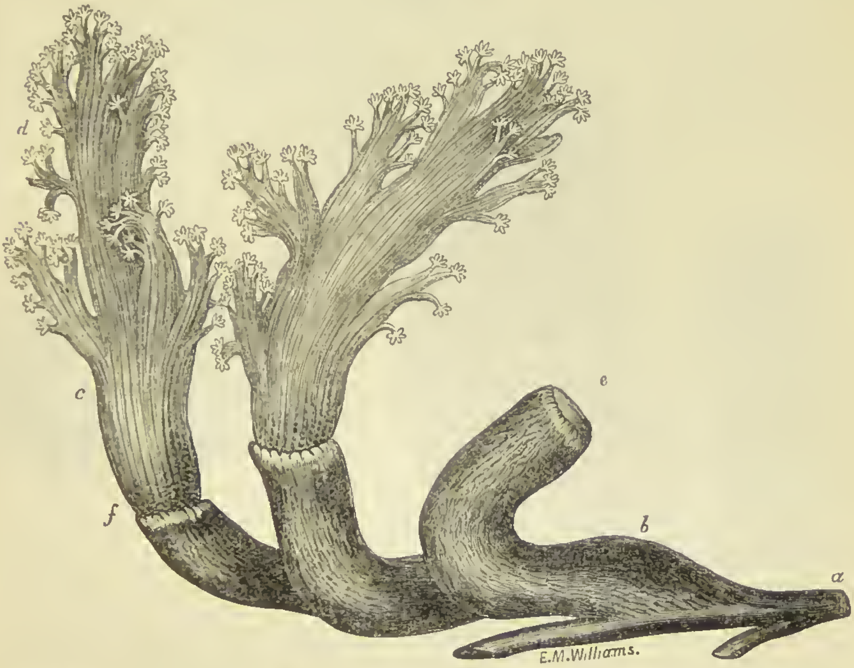
* Professor Grant, Lectures on Comparative Anatomy. Lancet for 1833–4, vol. ii. p. 261.

† Quoy et Gaimard, Zoologie du Voyage de l'Uranie. Paris, 1834.

‡ Mémoire sur un nouveau genre de la famille des Alcyoniens (genre Alcyonide). Ann. des Sc. Nat. 1835.

(*d*). Internally, the digestive sacculus presents eight longitudinal lines, and a multitude of minute transverse folds. Its inferior termination becomes suddenly contracted, as though the terminal orifice were closed by a sphincter muscle, and communicates with the wide abdominal cavity (*e*) that occupies the entire diameter of the lower portion of the polyp, and is prolonged inferiorly into the common body of the polypary. The calibre of the digestive tube is much smaller than that of the animal in the centre of which it is suspended; nevertheless it is firmly connected with the parietes of the polyp by the intervention of eight delicate membranous lamellæ derived from its outer surface (fig. 26, 1 & 2, *f*) and extending along its whole length. The position of these septa corresponds with the intertentacular spaces; and as by their upper extremities they are united to the peristomal disk, they form the walls of eight longitudinal canals which are uninterruptedly continuous with the cavities of the corresponding tentacula (fig. 26, 1, *g*). These last-mentioned appendages are completely hollow, and moreover present on each side of their internal cavity a series of ten or twelve minute apertures (fig. 26, *g'*) leading into the marginal pinnules, that are of similar structure.

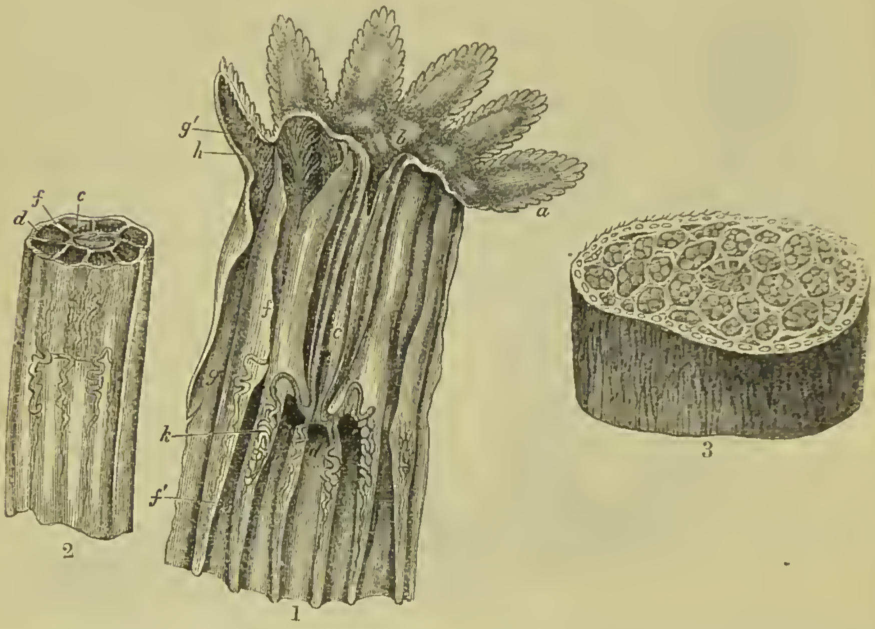
Fig. 25.



Alcyonidium elegans (after Milne-Edwards, Ann. des Sc. Nat. 1835, pl. 12. fig. 1). *a*, foreign body to which the polyp is attached; *b*, the hard portion, or coriaceous foot; *c*, the trunk, or membranous portion of the polypary; *d*, polypiferous ramifications of ditto; *e*, the soft parts of the trunk completely retracted into the coriaceous stem; *f*, yellow specks indicating the ova contained in the lower portion of the polypary.

(127.) Inferiorly, the eight longitudinal interseptal canals communicate freely with the great abdominal cavity (*e*), and the vertical partitions whereby they are separated become continuous with the longitudinal folds (*f*′) visible in its interior. The longitudinal plicæ are apparently of the same structure as the vertical septa of which they are

Fig. 26.



Anatomy of *Alcyonidium elegans* (after Milne-Edwards). 1. A polyp opened longitudinally to show its internal organization: *a*, the tentacula; *b*, mouth; *c*, alimentary canal; *d*, inferior opening of ditto; *e*, upper portion of the abdominal cavity; *f*, longitudinal septa passing between the parietes of the body and the walls of the digestive cavity; *f*′, continuation of the same into the abdominal cavity; *g*, canals formed between the septa, which are continuous with the interior of the tentacula; *g*′, one of the tentacles opened, showing the holes by which its cavity communicates with those of the marginal pinnules; *h*, minute spicula situated at the base of the tentacles; *k*, filiform appendages to the alimentary tube. 2. Transverse section, showing the manner in which the longitudinal plicæ are connected with the alimentary tube. 3. Section through the basilar portion of the polypary.

the continuations, only they are narrower, and their inner margin being free, they hang loosely in the abdomen of the polyp. On closer inspection they seem to be made up of two extremely thin membranous layers folded upon each other and continuous with the internal tunic that lines the parietes of the body. At the point of continuity the two laminæ become slightly separated, so as to leave a little canal at the base of each fold; while superiorly, close to the termination of the stomach, there is a remarkable filiform and very flexuous organ (fig. 26, 1, *k*), apparently an appendage to the alimentary cavity.

(128.) As has been stated above, the common polypary consists of two portions differing widely from each other in texture, forming the *trunk* and the *foot*. By dissection it becomes immediately apparent that the softer portion, named the trunk, is made up of membranous tubes disposed longitudinally parallel to each other, and so closely connected together that it is difficult to separate them. The *foot* of the polypary is essentially nothing more than a continuation of these same tubes modified in structure: those situated near the centre of the stem have their walls only slightly thickened; but those placed near the periphery acquire a more solid consistence, from having their parietes incrusted with innumerable fusiform spicula composed of carbonate of lime imbedded in a cartilaginous substance; these are arranged longitudinally (fig. 26, 3), and give to the stem its solidity and peculiar aspect. Near the circumference of this portion of the polypary longitudinal fibres are perceptible, which appear to be the remains of tubes atrophied by compression (fig. 27, 3, *a*).

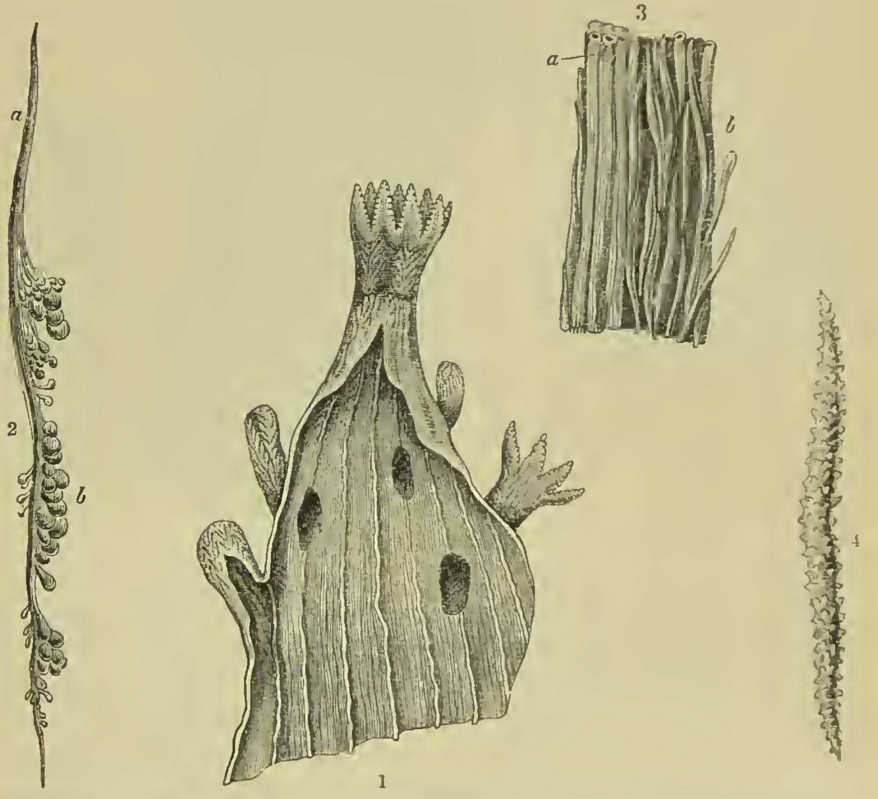
(129.) The tubes thus united in fasciculi are evidently analogous to the cavities into which the polyps of Alcyons, Corals, &c., are retracted: these have generally received the name of "polypiferous cells;" and some authors consider them as being quite distinct from the animals inhabiting them: in the zoophyte under consideration, however, a very superficial examination is sufficient to prove that they are really merely continuations of the bodies of the polyps themselves, no line of demarcation being distinguishable between them. It is not, therefore, into polypiferous cells that these little flower-like creatures retire, but become retracted into their own bodies by a species of invagination; and the entire polypary which seems to afford them lodging is nothing but a mass formed by the aggregated tubes of all the polyps belonging to it.

(130.) It appears to be pretty generally admitted that among the aggregated polyps nutritive materials swallowed by one individual goes to the sustenance of the general community—an opinion seemingly based upon observations made upon certain Sertularian species: but that a similar community of nutrition exists in the *Alcyonidæ* remained, prior to the researches of Milne-Edwards, an unsolved question; neither was anything known precisely as to the relationship existing between these aggregated beings; or, even admitting, from analogy, the most intimate union, it was difficult to conceive how nutritive matters were conveyed from one polyp to another, whether by simple imbibition or in any other manner.

(131.) In order to solve these questions so far as relates to the Alcyonidium under consideration, Milne-Edwards, by means of a small glass tube having its end drawn out fine in the flame of a lamp, injected a coloured fluid into the abdominal cavity of one of the polyps, and found that the injection immediately passed into the abdominal cavities of the polyps around; consequently the nutritive substances swallowed by any individual can be distributed among the different members of these remarkable colonies, so that food taken by one may nourish the neighbouring animals.

(132.) On cutting one of these polyps open under a magnifying glass, it is easy to explain how this intercommunication is effected: it then becomes apparent that some of the animals, as described above, terminate in tubular prolongations, whereof the general substance of the polypary seems to be made up; others, however, sprouting immediately from the parietes of the former, have their internal cavity continuous with that of the larger central polyp, so that a free communication is kept up between them (fig. 27, 1), the whole forming a sort of ramified tube, or an animal having one body and one central stomach, but furnished with many heads and as many mouths.

Fig. 27.



Anatomy of *Alcyonidium elegans* (after Milne-Edwards). 1. One of the branches of the polypary opened to show the communication which exists between the abdominal cavity of the principal polyp and the interior of the young ones sprouting therefrom: the apertures, it will be observed, are always in the track of the longitudinal ovarian folds. 2. Lower portion of an ovarian fold detached from the walls of the abdominal cavity to show the manner in which the ovules or gemmæ are developed. 3. A portion of the foot, or basilar portion of the polypary: *a*, membranous tubes; *b*, spicula incrusting this portion of the polypary. 4. A spiculum magnified.

(133.) The development of these secondary polyps is effected by a simple process of gemmation. A tubercle makes its appearance upon the surface of the primary animal, which looks at first like a little cæcum appended to the integument, having no oral aperture, but communicating freely, by means of its central canal, with the abdominal cavity of its parent. When arrived at a more advanced stage of development, the tentacula make their appearance and the alimentary canal becomes distinguishable, so that the young animal soon exhibits an exact representative of the original from which it sprung.

(134.) But here it is necessary to observe that this kind of vegetation does not take place indiscriminately from any portion of the tegumentary surface of the polyp. The reproductive gemmæ are only formed immediately over the track of one of the eight longitudinal membranous lamellæ above noticed (fig. 27, 1), so that the apertures of communication between the newly formed polyps and the original are always so placed as to interrupt the course of one of these folds.

(135.) It is not, however, only by the development of buds that the reproduction of the Alcyonidium is effected. These animals likewise produce ovules or gemmules adapted to spread to a distance their sedentary race; and it is worthy of remark that the same organs from which the gemmæ above described derive their origin, perform the functions of the ovaria of higher animals.

(136.) It is in the longitudinal membranous folds above described that the reproductive gemmules are developed (fig. 27, 2), which, as they increase in size, become pedunculated, and ultimately fall off into the abdominal cavity, whence they easily escape through the mouth of the polyp.

(137.) The intestiniform convoluted organs (fig. 26, 1, *k*), situated beneath the alimentary cavity, are, from what has been stated above, evidently not the ovaria, seeing that the ova are formed elsewhere; neither, from the simplicity of the structure of the reproductive apparatus, can they be regarded as male organs destined to fertilize the ova; so that, upon the whole, it seems most probable that they represent hepatic vessels.

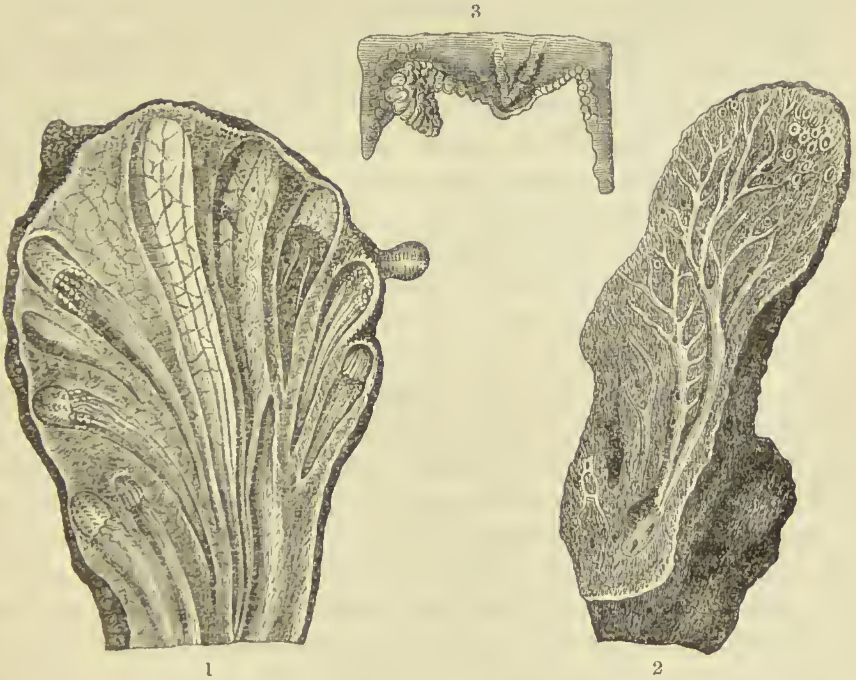
(138.) When the polyps are expanded, their mouths are frequently seen to dilate and take in the surrounding water, which, together with such alimentary substances as may be suspended in it, penetrates into the digestive canal, and through this passes into the general cavity of the abdomen, whence again it mounts up into the tentacula through the eight canals that surround the alimentary tube. It results from this arrangement, that the thin and variously folded membrane composing the bodies of these animals is bathed throughout with the water required for respiration, and that all its internal surface is placed in contact with the nutritivo matters moro or less elaborated in the stomach.

(139.) On seeing the same animal producing sometimes buds or gemmæ, and sometimes ova, Milne-Edwards was led to inquire into the cause of this difference, which he believes to be of a mechanical nature. In those parts of the polyp which are not yet imprisoned in the growing mass of the polypary, reproduction is generally effected by the development of external buds, while towards the base of the polypary, where the constituent zoophytes are intimately united together by their outer surface, and are surrounded by a sort of sheath, no external buds are formed, but the ovules make their escape into the internal cavity of their parent. Hence the distinguished zoologist whose memoir we quote is led to infer that, on the one hand, the mechanical obstacles to be encountered, and, on the other, the excitement occasioned by the contact of the surrounding element determine this difference of procedure, and that the membrane which performs the functions of an ovary produces indifferently either ova or gemmæ, according as it finds less resistance or is more stimulated upon the inside or the outside of the abdominal walls.

(140.) From the above details it becomes easy to explain how a single polyp by its reproductive powers can form the complicated mass of the compound polypary of the Alcyonidæ, as well as the means whereby an organic continuity is established between all the individuals of the community; also how the abdominal cavity of the primitive zoophyte becomes common to all the young ones that sprout from it; in short, how the little beings thus united together rather resemble a multiple animal than an assemblage of distinct individuals. But with the advance of age this intimate union gradually ceases. The communication between the abdominal cavities of the different polyps, whose basal portions reach as far as the foot of the polypary, is first of all interrupted by the ova with which the lower part of these cavities becomes filled (fig. 26, 3); and subsequently, by the pressure of the surrounding parts, the wall becomes confused, and all communication between the polyp whose abdominal tube is thus obliterated and the polyp from which it sprung is intercepted. The polypary, instead of resembling a tree, all the flowers of which hold together and communicate by common parts, may now be compared to a bouquet made by cutting off the more or less branched twigs of a plant and collecting them in a bundle. The different groups of polyps united in the same polypary become thus independent of the neighbouring groups, and, as may readily be conceived, in time each polyp can become individualized.

(141.) In the Alcyons properly so called, a vascular system is very distinctly developed; and in *Alcyonium stellatum* more especially. M. Milne-Edwards was able to study it with facility. In this species (fig. 28, 1) he was enabled to detect, upon the parietes of the abdominal cavity of the polyp, a variable number of minute apertures irregularly dispersed, which are in immediate communication with a system of capillary canals that traverse in all directions the spongy portion of the polypary, formed by the external tunic of its component animals; for in *Alcyonium* it is very easily seen that while the internal tunic lines the abdominal cavity of the polyp, the external layer, instead of being confounded with the former, as in the protractile portion of the animal, becomes perfectly distinct from it where it begins to enter into the composition of the polypary, at which point its thickness is considerably augmented, its texture spongoid, and in its substance are deposited a number of irregular crystals, composed of carbonate of lime mixed with a little colouring matter. In the tegumentary mass thus formed the vascular canals ramify, anastomosing freely among themselves, so as to constitute a vascular network. These vessels are formed of very attenuated membrane of a yellowish colour, which is continuous with the internal tunic of the polyps, and is perfectly distinguishable from the dense tissue with which it is surrounded. The distribution of these canals is best displayed by cutting a thin slice of the mass of the Alcyon, and removing the crystals with which it is filled by immersion in some dilute acid; it is then seen that the canals are most numerous and of the largest size towards the extremities of the branches of the polypary, and that they establish frequent communications between the abdominal cavities of the different polyps of the Alcyon. The fluids with which their bodies are filled must thus necessarily circulate in the entire mass of the polypary; and if each of the polyps has, on the one hand, an individual sensibility and a distinct digestive cavity, on the other there is a vascular system common to them all.

Fig. 28.



1 & 2. Sections of *Alcyonium stellatum*. 3. Ovigerous membrane of the same, isolated.

(142.) The Alcyons, like the Alcyonides, are reproduced by ova, which are formed in membranous ovaria of precisely similar construction; and also by gemmæ, which are developed around the pre-existent polyps, and thus augment indefinitely the number of individuals united upon one stock. There is, however, a very important difference observable between these two genera of zoophytes, in other respects so similar. In the Alcyons the abdominal cavity of the young polyps is not directly continuous with the abdominal cavity of their parent, and it is only by the intermedium of the vascular system, described above, that they are placed in communication with each other—a modification which depends upon a difference in the mode of formation of the reproductive gemmæ. When an Alcyon stock is about to put forth a new branch, the spongy part of the polypary (that portion which is formed by the external tunic of the polyps, and permeated by the vascular network) begins to increase in size at some determinate point of its periphery, and soon produces a tubercle of greater or smaller size, into which the vessels spoken of above are continued, and form numerous anastomoses with each other. At this early period of development the new branch presents no trace of polyps; but its vascular tissue is nevertheless already studded with calcareous crystals, and exactly resembles that situated in other parts of the common mass, between the abdominal cavities of the adult polyps; it must therefore necessarily be traversed by the currents which circulate in the general vascular system. On dissecting one of these newly formed branches, the vestiges of young polyps may be distinguished; and if the sprouts examined are still further advanced, it is easy to distinguish the young animals within, already possessing the form they will afterwards exhibit, but having not yet established a communication with the exterior (fig. 28, 1). At length, however, this communication is effected; the newly formed polyp only differs from the pre-existing ones in its small size; and as it grows, its increase causes the enlargement of the polypary. In this case it is very evident that the part which gives birth to the reproductive gemmæ is no portion of the individual polyps of the Alcyon, but is common to them all. The generative tissue surrounds these little beings with a sort of living sheath, and produces in the interior of its own substance new polyps, quite independently of those previously in existence. These polyparies might therefore be compared to a sort of common ovary, the products of which are never completely individualized, but remain permanently lodged in its substance, and minister to the support of its existence and the aggrandizement of its tissue.

(143.) This singular mode of reproduction, M. Milne-Edwards observes, seems at first sight to be very different from that observed in the Alcyonidium; but on reflection, a considerable analogy may be traced between them. In *Alcyonidium* the internal tunic of the abdominal cavity fulfils the functions of an ovary, and produces at determinate points both gemmæ and ova; in *Alcyon*, on the contrary, while the internal membranous layer gives birth to ova, the gemmæ are developed elsewhere, from the canals which permeate the common mass. But the membrane which forms these canals, and which is the seat of this kind of vegetative reproduction, is merely a continuation of the internal tunic; and hence it is easy to understand how it may fulfil analogous functions.

(144.) Madreporidæ.—Were we to imagine one of the Alcyonidæ capable of secreting not merely the calcareous spicula that are mixed up with the softer portions of its body, but abundant quantities of carbonate of lime, which, being stored up in the centre of its substance, should form a dense calcareous axis incrusted with the uncalcified part of the living animal, and perforated at its surface so as to form innumerable cells or lodges adapted to contain the polyps that provide nourishment for the common mass, we should have a good general idea of the structure of the tribe of polyps that next comes beneath our notice.

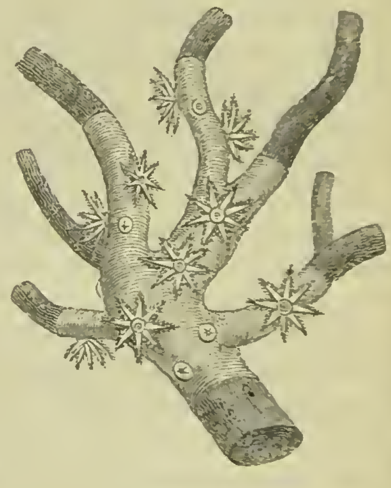
(145.) The shallower parts of the tropical seas contain countless forms of madrepores, known to us, unfortunately but too often, only by detached fragments of the earthy skeletons which the beauty of their appearance induces the mariner to bring to our shores. These calcareous masses generally assume more or less an arborescent appearance, spreading to a considerable extent, so as to cover the bottom of large tracts of the ocean, and not unfrequently they play an important part in producing geological changes, which are continually witnessed in the regions where they are abundant.

(146.) In the hot climates in which the saxigenous corals abound, they are found to frequent shallow bays and sheltered spots, where they can enjoy the full influences of light and air, unexposed to the agitation of the ocean, which, were it to beat continually upon them, would infallibly destroy their delicate substance: in such situations, the submarine rocks become gradually incrusted with the calcareous skeletons which they produce; and if undisturbed, in the lapse of years successive generations will of course deposit such large quantities of calcareous matter as to form beds of considerable thickness. That there are at the bottom of the ocean bold and precipitous cliffs, rising from a depth of 1000 or 1200 feet, their broad tops approximating the surface of the ocean, every one will admit, without having recourse to the labours of madrepores to account for their formation, although the sheltered portions of the summits of such mountain-ridges afford an eligible position for their increase. In such situations, therefore, they accumulate, and slowly deposit continually increasing masses of earth upon the brow of these submarine mountains, until at last the pile approaches the surface of the sea, and even, at low water, remains uncovered by the waves. The further elevation of the rock, as far as the polyps are concerned in its construction, here ceases; but a variety of causes tend gradually to heap materials upon the newly appearing island: storms, which tear up the bottom of the sea, perpetually throw to the surface sand and mud, which becoming entangled among the madrepores, and matted together with sea-weed, forms a solid bed over which the waves have no longer any power. The circumference of the islet is perpetually augmented by the same agency: sea-weeds and vegetable substances cast upon it, by their decay cover its top with vegetable mould; and if its proximity to other land permit the united action of winds and currents to bring the germs of vegetation from neighbouring coasts, they take root in the fresh soil, and soon clothe with verdure a domain thus rescued from the ocean.

(147.) Corallidæ.—The Corallidæ are compound polyps of apparently more perfect organization than those forming the last family. The polypary or central axis, which supports the external or living crust, is solid, without cells, and variously branched,—the larger species resembling shrubs of great beauty, frequently coloured with lovely hues, and studded over their whole surface with living flowers; for such the polyps which nourish them were long considered even by scientific observers. The central stem of these zoophytes differs much in its composition in different families, sometimes being of stony hardness; in other cases it is soft and flexible, resembling horn; and not unfrequently it is formed of both kinds of material: it is, however, always produced by the living cortex, which secretes it in concentric layers, the external being the last deposited.

(148.) The example which we shall select for special description is the coral of commerce, *Corallium rubrum* (fig. 29), from which we derive the material so much prized in the manufacture of ornaments.

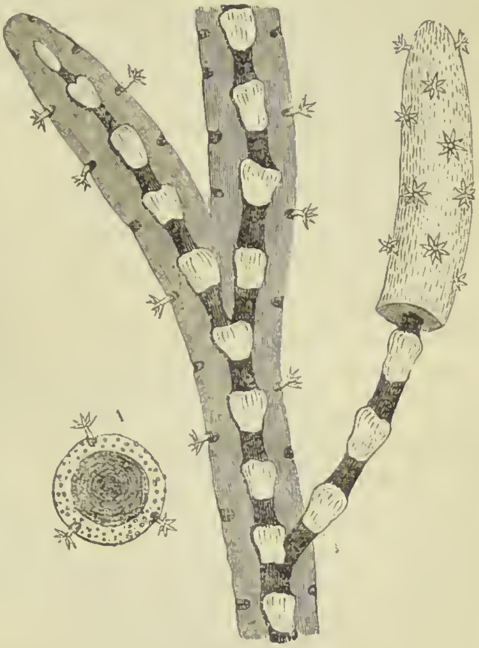
Fig. 29.



Corallium rubrum.

(149.) The red coral is principally obtained in the Mediterranean. When growing at the bottom of the sea, it consists of small branched stems, incrusted with a soft living investment, by which the central axis is secreted, and studded at intervals with polyps possessing eight fringed arms, and capable of being contracted into cells contained in the fleshy covering, but not penetrating the stem itself. The skeleton or polypary of the coral is of extreme hardness, and susceptible of a high polish—a circumstance to which the estimation in which it is held is principally owing. But in other genera of this family, the central axis, instead of being constructed of calcareous matter, is formed of concrete albumen, and resembles horn both in appearance and flexibility; such are the Gorgoniæ of the Indian Ocean. In the *Isis hippuris* (fig. 30, B) the central axis is alternately composed of both these substances, exhibiting calcareous masses united at intervals by a flexible material, allowing the stem to bend freely in every direction. The object of such diversity in the texture of the polypary of the Corallidæ will be at once apparent when we consider the habits of the different species. The short and stunted trunks of *Corallium*, composed of hard and brittle substance, are strong enough to resist injuries to which they are exposed; but in the tall and slender stems of *Gorgonia* and *Isis*, such brittleness would render them quite inadequate to occupy the situations in which they are found, and the weight of the waves falling upon their branches would continually break in pieces and destroy them; this simple modification, therefore, of the nature of the secretions with which they build up the skeleton which supports them allows them to bend under the passing waves, and secures them from otherwise inevitable destruction.

Fig. 30.



A, transverse section of *Gorgonia verrucosa*.
B, longitudinal section of *Isis hippuris*, exhibiting the skeleton and fleshy crust.

(150.) Upon making a transverse section of one of these polyparies (fig. 30, A), the solid axis is distinctly seen to be made up of layers arranged in a somewhat undulating manner around the centre, and successively deposited by the living cortex: the growth of the stem, in the harder species at least, is very slow, and several years are necessary to its maturity,—a circumstance which has rendered it needful to impose strict laws forbidding the Mediterranean coral-fishers to disturb too frequently the same localities, which are only visited at stated periods.

(151.) The deposition of solid matter in the soft bodies of these polyps is not confined to the production of the central stem, but in many even of the Keratophyta* cretaceous particles are extensively diffused through the cortex, which not unfrequently is likewise gorgeously coloured by secretions of different hues. In the Gorgoniæ, a section of one of which (*Gorgonia verrucosa*) is represented in fig. 30, A, the earthy matter in the crust is so abundant, that even when dried it will retain in some measure its natural form, and exhibit the tints peculiar to the species.

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* An old name for polyps with a horny axis (κέρας, horn; φυτὸν, a stem), as distinguishing them from the stony polyps—*Lithophyta* (λίθος, a stone; φυτόν).

(152.) The structure of the individual polyps of the Corallidæ resembles that of one of the polyps of the Alcyonidæ already described; and the prey obtained by each goes to the support of the general mass. Their reproduction is undoubtedly from germs developed in internal filamentary ovaria, which escape either through the mouth, as in *Alcyonium*, or else, as Cavolini* supposed, through apertures placed between the origins of the tentacles.

(153.) Pennatulidæ.—This family belongs likewise to the division of cortical polyps, and agrees with the two last in most points, the principal distinction consisting in the character of the internal axis which supports the body. In some species this part is reduced to a ligamentous mass, interspersed with calcareous granules; but in the most typical forms the skeleton consists of several pieces, capable of moving upon each other. The whole animal in such cases resembles a feather, the stem supporting lateral branches, upon which the polyps are arranged. From the circumstance of these compound animals being unattached to any foreign support, they have been supposed to be capable of swimming at large in the sea, by the voluntary movements of their articulated branches—a fact strongly contested by many modern zoologists; but as we can say nothing from our own observation upon this subject, we must leave the question open to future investigation. Many species are eminently phosphoric.

Fig. 31.

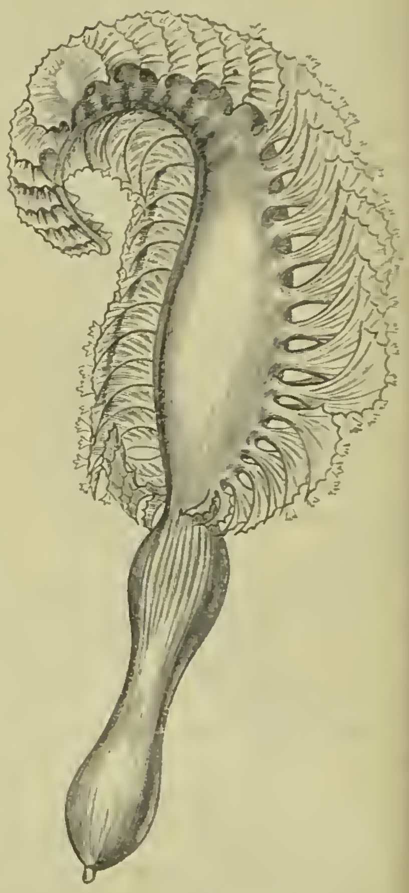

Figure of Pennatula.

(154.) Tubiporidæ.—We have now to speak of a class of polyps very different in their construction from those which have been described. Instead of incrusting an internal solid skeleton, the Tubiporidæ are enclosed in a calcareous or coriaceous sheath or tube, from the orifice of which the polyp is protruded when in search of prey: these are named by authors *Vaginated Polyps*.

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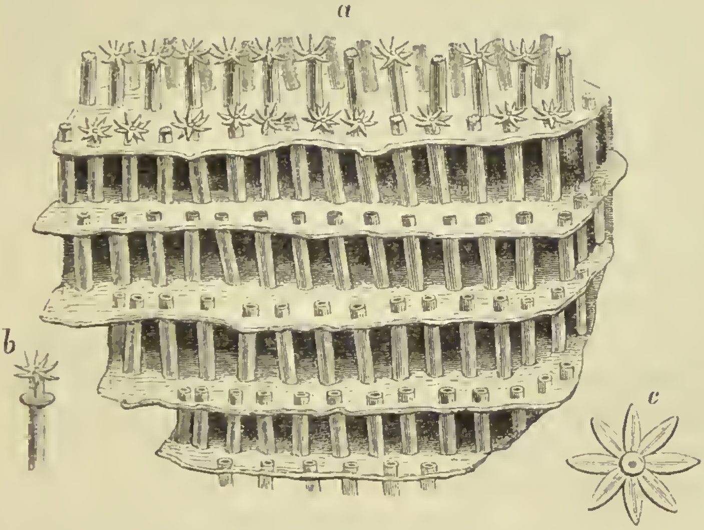
* Cavolini (Filippo), Memorie per servire alla storia dei Polipi marini. 4to. Naples, 1785.

(155.) The *Tubipora musica* (fig. 32, *a*) is the species which has been most carefully studied; and the details connected with its organization will be found of the highest importance, as affording a clue to the investigation of other forms, to be mentioned hereafter. The Tubiporæ live in society, but do not appear to be organically united as the compound polyps are. A group of these animals presents several stages of tubes, placed one above another (fig. 32, *a*): the tubes are generally straight, and nearly parallel to each other, but appear slightly to diverge as radiating from a common centre; they are separated by considerable intervals, and reciprocally support each other by horizontal laminæ of the same substance as the tubes themselves, which unite them. From each tube a polyp is protruded, of a brilliant grass-green colour, sometimes of a lilac or rose tint, the mouth being surrounded by eight tentacles, which are furnished along their edges with two or three rows of minute fleshy papillæ.

Fig. 32.



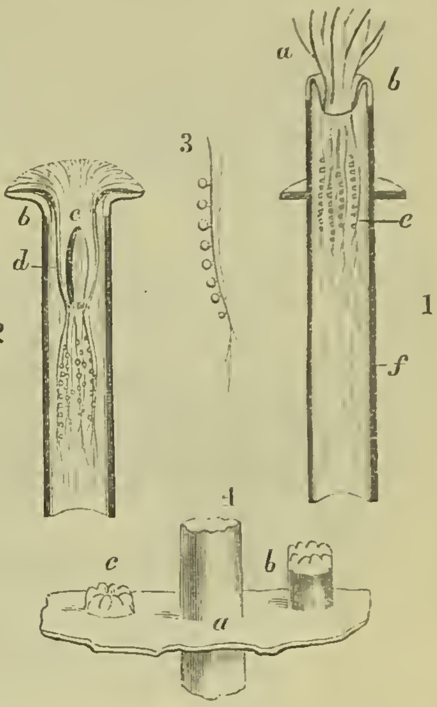
Tubipora musica. *a*, a portion exhibiting several stages of tubes; *b*, an isolated tube; *c*, polyp expanded.

(156.) The visceral cavity is long, tubular, and contains eight fleshy lamellæ (fig. 33, 1, *e*). These lamellæ aid, by their muscles, both in the contraction and expansion of the polyp. The stomach is very short compared with the whole length of the visceral cavity, and, as in the Alcyonium figured above, is connected with the sides of the cavity by the visceral lamellæ.

Six of these lamellæ, in a specimen examined by Dana, were spermatic, being bordered below by a white convoluted cord, while the other two gave origin to large clusters of milk-white ovules, which occupied nearly the whole diameter of the cavity. These ovules were of various sizes, and spherical in shape, or nearly so. Some observers have found all the lamellæ bordered with white filaments; and others describe them as all bearing clusters of ovules. In these instances it would seem that the sexes are distinct, in one case the animal being male, in the other female. The ovules have been seen to escape by the mouth; and this therefore appears to be the general mode in all the Actinoid polyps.

(157.) At the point where the ovigerous laminæ reach the tentacles a membrane is observable, which assumes the shape of a funnel when the animal retires into its shell; and at the open end of the funnel the membrane is seen to fold outwards and become continuous with the calcareous tube (fig. 33, 1, *b*); its inner surface, indeed, is prolonged under the form of a thin pellicle over all that part of the interior of the tube which is inhabited by the polyp, terminating at a kind of diaphragm composed of the same hard substance as the tube itself. The remains of these diaphragms are found in the interior of old tubes at various distances from each other.

Fig. 33.



Anatomy of *Tubipora*. 1. *a*, Polyp partially expanded: *b*, flexible extremity of the tube; *e*, ovigerous laminæ; *f*, calcareous portion of the tube. 2. *b*, Expanded extremity of the tube, still uncalcified; *c*, polyp retracted; *d*, inflected membrane embracing the neck of the polyp. 3. Ovarian lamina detached. 4. Development of young: *a*, horizontal stage; *b*, *c*, growing offspring.

(158.) The funnel-shaped membrane does not terminate suddenly at its point of junction with the calcareous tube; the latter, indeed, is a continuation and product of the first, the calcareous substance being evidently deposited in this gelatinous membrane in the same manner as phosphate of lime is deposited in the bones of very young animals, changing its soft texture into hard, solid substance. The manner therefore in which this tube is formed cannot be compared to the mode of formation of the shells of *mollusca*: in the latter case it is a secretion from the skin, an epidermic product; but in these polyparies there is a real change of soft into solid substance, which is effected gradually, but not deposited in layers.

(159.) When the tube has acquired a certain height, the animal forms the calcareous horizontal plate which unites it to those around:

the still membranous upper part of the tube extends itself horizontally outwards around the aperture (fig. 33, 2, *b*), doubling itself so as to form a circular fold: this part of the membrane is no longer irritable; its internal surfaces unite, so as not to interrupt the continuity of the tube; carbonate of lime is gradually deposited within it; and soon a prominent partition, composed of two lamellæ, soldered together through almost their entire extent, surrounds the tubular cell. Generally many polyps of the same polypary form these partitions at the same time and upon the same plane. In this case the gelatinous margins of the folded membrane unite, no space is left, and they ultimately become most intimately soldered together, and the solid plane or stage (fig. 32) is formed. If the animal construct its partition against a tube already perfect and solidified, it fixes its collar to its sides, so that the point of junction is imperceptible; but when it is quite insulated, as at *b*, fig. 32, the horizontal collar is still formed, and it then assumes somewhat of an octagonal shape. The tube-forming membrane exhibits no appearance of vessels or other traces of organization.

(160.) When the polyp is withdrawn within its cell, its tentacles form a cylindrical fasciculus (fig. 33, 2, *c*), the papillæ which partially cover them being laid upon each other like the leaflets of some *Mimosæ* when asleep.

(161.) The protrusion of the creature from its tube is accomplished by the contraction of the membrane, *b*, inserted into its neck.

(162.) The germs, during the first period of their development, have no organs distinguishable, not even the rudiment of a tube; each appears to consist of a simple gelatinous membrane folded upon itself (fig. 33, 4, *c*), and forming upon the stage upon which it is fixed a little tubercle resembling a small *Zoanthus* or other naked zoophyte. This tubercle gradually elongates, and assumes the form of a polyp, provided with all its organs; but the sac which encloses it is still gelatinous at its upper part and membranous near the base (fig. 33, 4, *b*), where it gradually diminishes in thickness, and, becoming calcareous, gives to the animal the general appearance of its original.

(163.) An extensive and important group of the Anthozoa, from the fibrous character which the substance of their bodies assumes, have been named by zoologists "*Fleshy Polyps*;" nevertheless, although the genera composing this division are exceedingly numerous, and vary much in their external characters, they will be found to conform, in the essential points of their organization, with the corals above described. The subject we have selected as the type of these beautiful zoophytes is a well-known *Actinia*, which being common upon our own coasts, the reader will have little difficulty in procuring specimens for examination, or for preservation in a marine aquarium, of which they will form conspicuous ornaments.

(164.) The body of an Actinia, when moderately expanded (fig. 34), is a fleshy cylinder, generally found attached by one extremity to a rock, or some other submarine support, whilst the opposite end is surmounted by numerous tentacula arranged in several rows around the oral aperture (fig. 35). When these tentacula are expanded, they give the animal the appearance of a flower, the deception being rendered more striking by the beautiful colours they not unfrequently assume; and hence, in all countries, these organisms have been looked upon by the vulgar as *sea-flowers*, and distinguished by names indicative of the fancied resemblance. Their animal nature is, however, soon rendered evident by a little attention to their habits. When expanded at the bottom of the shallow pools of salt water left by the retreating tide, they are seen to manifest a degree of sensibility, and power of spontaneous movement, such as we should little anticipate from their general aspect. A cloud veiling the sun will cause their tentacles to fold, as though apprehensive of danger from the passing shadows; contact, however slight, will make them shrink from the touch; and if rudely assailed, they completely contract their bodies, so as to take the appearance of a hard coriaceous mass, scarcely distinguishable from the substance to which they are attached.

Fig. 34.

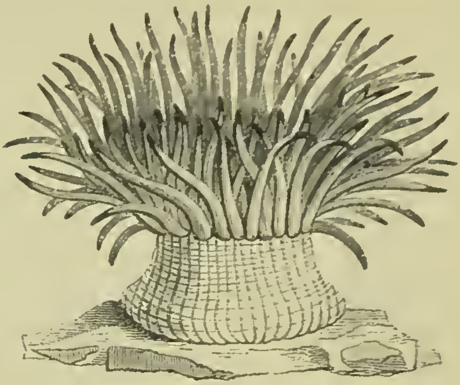
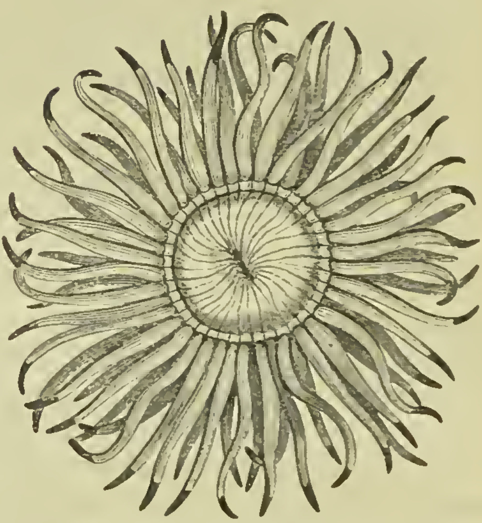


Fig. 35.



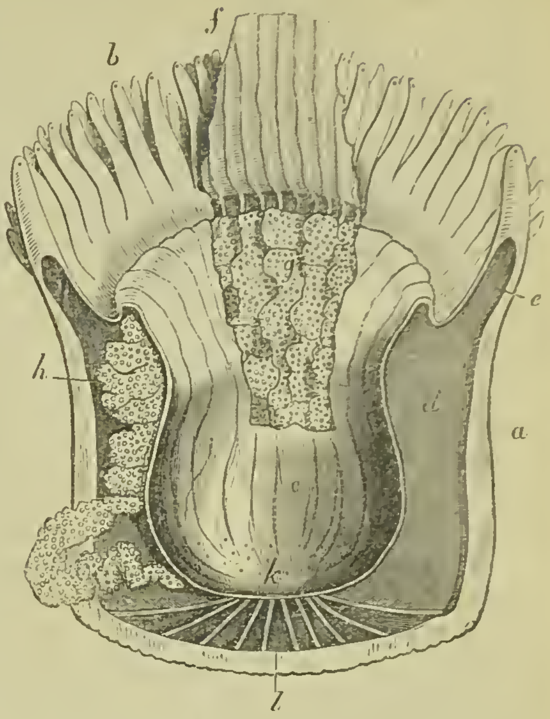
(165.) It is in seizing and devouring their prey, however, that the habits of the Actiniæ are best exemplified. They will remain for hours with their arms fully expanded and motionless, waiting for any passing animal that chance may place at their disposal, and when the opportunity arrives are not a little remarkable for their voracity and for their capability of destroying their victims. Their food generally consists of crabs or shell-fish, animals apparently far superior to themselves in strength and activity; but even these are easily overpowered by the sluggish yet persevering grasp of their assailant. No sooner are the tentacles touched by a passing animal than it is seized, and held with unfailing pertinacity; the arms gradually close around it; the mouth, placed in the centre of the disk, expands to an extraordinary size; and the creature is soon engulfed in the digestive bag of the Actinia, where the solution of all its soft parts is rapidly effected, the hard undigestible remnants being subsequently cast out at the same orifice.

(166.) The Actiniæ possess the power of changing their position: they often elongate their bodies, and, remaining fixed by the base, stretch from side to side, as if seeking food at a distance: they can even change their place by gliding upon the disk that supports them, or detaching themselves entirely, and swelling themselves with water; they become nearly of the same specific gravity as the element they inhabit, and the least agitation is sufficient to drive them elsewhere. When they wish to fix themselves, they expel the water from their distended body, and, sinking to the bottom, attach themselves again by the disk at their base, which forms a powerful sucker.

(167.) From the above sketch of the outward form and general habits of these polyps, the reader will be prepared to examine their internal economy and the more minute details of their structure. On examining attentively the external surface of the body, it is seen to be covered with a thick mucous layer resembling a soft epidermis, which, extending over the tentacula, and the fold around the aperture of the mouth, is found to coat the surface of the stomach itself: this epidermic secretion forms, in fact, a deciduous tunic, that the creature can throw off at intervals. On removing this, the substance of the animal is found to be made up of fasciculi of muscular fibres, some running perpendicularly upwards towards the tentacula, while others, which cross the former at right angles, pass transversely round the body; the meshes formed by this interlacement are occupied by a multitude of granules, apparently of a glandular nature, giving the integument a tuberculated aspect: these granules are not seen upon the sucking-disk at the base. The tentacula are hollow tubes, composed of fibres of the same description. The stomach is a delicate folded membrane, forming a simple bag within the body; it seems to be merely an extension of the external tegument, somewhat modified in texture.

(168.) On making a section of the animal, as represented in fig. 36, the arrangement of these parts is distinctly seen, *a* being the muscular integument; *b*, the tentacula, formed by the same fibrous membrane; and *c*, the stomach. Between the digestive sac, *c*, and the fibrous exterior of the body, *a*, is a considerable space, *d*, divided, by a great number of perpendicular fibrous partitions, *l*, into numerous compartments, which, however, communicate freely with each other and likewise with the interior of the tentacula, as seen at *e*. Every tentacle is perforated at its extremity by a minute aperture, *b*, whereby the sea-water is freely admitted into these compartments, so as to bathe the interior of the body; and when, from alarm, the animal contracts itself, the water so admitted is forcibly expelled in fine jets through the holes by which it entered. There can be no doubt that the surrounding fluid, thus copiously taken into the body, is the medium by which respiration is effected; and every one who has been in the habit of keeping Actiniæ in glass-vessels for the purpose of watching their proceedings must have noticed that, as the fluid in which they are confined becomes less respirable, from the deficiency of air, the quantity imbibed is enormous, stretching the animal until it rather resembles an inflated bladder than its original shape.

Fig. 36.



Section of *Actinia.*

(169.) It is in the compartments thus (at the will of the creature) distended with water that we find the organs of reproduction, which here assume a development far exceeding what we have noticed in other zoophytes. On raising a portion of the membrane forming the stomach, as at *f*, we see lodged in each partition an immense number of granular corpuscles attached to a delicate transparent membrane, and arranged in large clusters, *g*. The ovigerous membrane that secretes these corpuscles is represented unravelled at *h*; it is through its whole extent bathed with water admitted into the compartment wherein it is lodged—a circumstance which provides for the respiration of the embryos during their development.

(170.) We learn from the researches of MM. Kölliker and Erdl that the Actiniæ are bisexual, and that the male and female organs are allotted to different individuals, the testes of the male and the ovaria of the female being so similar in their structure and appearance that the difference between them is only appreciable with the microscope.

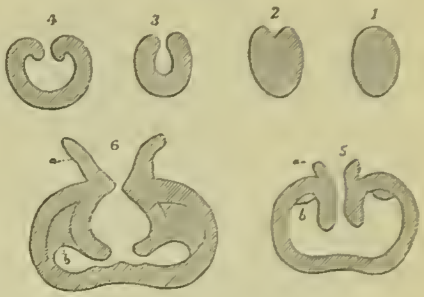
In both sexes the reproductive apparatus consists of riband-like convolutions attached by delicate membranous folds to the free margins of the septa, and filled with multitudes of the granular-looking bodies above mentioned, which in the females are the ova, in the males the spermatic capsules. In neither sex is there any excretory duct; so that the eggs, when mature, must escape immediately into the general cavity of the body by bursting through the delicate membranous envelope in which they are enclosed. The whole exterior of the organ is densely ciliated.

When examined under the microscope, the granules extracted from their investment are found, in the male, to contain immense numbers of caudate and very active spermatozooids,—while those of the female are real ova, of spherical shape, and furnished with a distinct yelk and germinal vesicle.

(171.) It is during the months of August and September that the generative system of our native species is in full activity and development. The ovum, it would seem, when arrived at maturity, breaks loose from the ovarian nidus; and as the number of males in a given locality is pretty nearly the same as that of the females, and they are always more or less found in company notwithstanding their sedentary habits, the eggs of the female would seem to be impregnated by the seminal fluid of the other sex, diffused through the surrounding water.

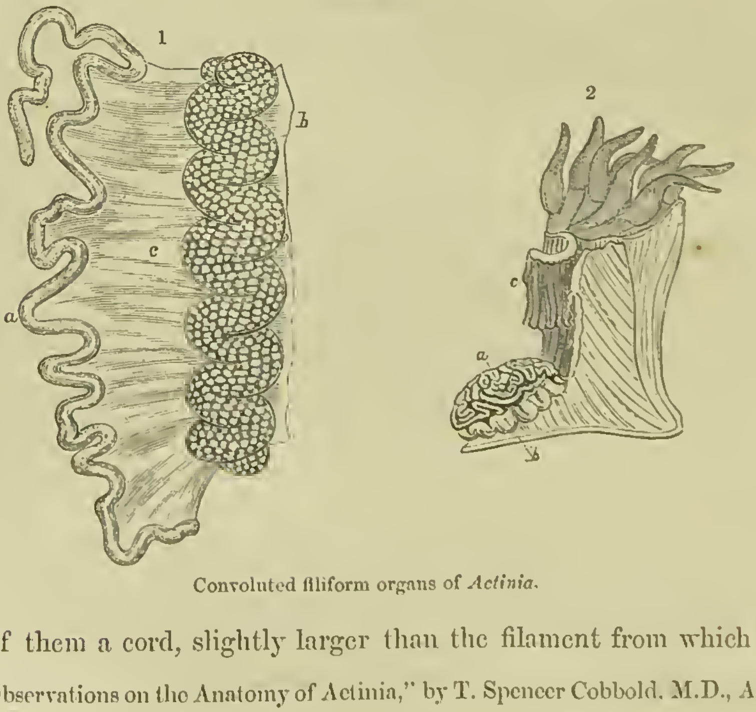
(172.) In *Cerianthus membranaceus*, however, a complete hermaphroditism exists, all the convolutions of the reproductive ribands being equally supplied with both the male and female elements of generation, in the shape of minute capsules, some of which enclose an ovule, whilst the others are filled with spermatozoa. These two kinds of capsules are scattered promiscuously, without any regular order, but always so that the ovigerous and spermatogenous organs are closely in contact. The ovules on quitting their ovarian nidus fall into the general perivisceral cavity, where they may be found of a spherical or oblong shape, and each presenting a distinct Purkinjean vesicle. The act of fecundation in this case appears to take place in the ovarian laminæ, and probably by the rupture of the delicate walls which circumscribe the contents of the male and female capsules. The eggs found in the ovaria are round and of a yellow colour, resembling minute grains of sand, and densely ciliated. There exists a considerable opening in the base of the stomach, whereby a free communication is established between the interseptal spaces and the general abdominal reservoir, through which the young Actiniæ are expelled in a very advanced state of development into the stomach, and from thence pass through the mouth into the surrounding water. The smallest germs are semi-opake spherical bodies, while the more advanced present every gradation of form from the simple sphere up to the complete tentaculate polyp. The largest are about the size of peas. On section they present appearances similar to those exhibited in the annexed diagrams (fig. 37), intended to illustrate the manner in which the morphological changes are brought about and the several special organs of the Actinia unfolded. The figures may be thus explained:—1. Outline of the mature embryonic corpuscle after the disappearance of the cilia with which, at an earlier stage, it is furnished. 2, 3, 4. Primary involution of the integumentary membrane. 5, 6. Re-induplication of the external membrane and formation of a stomachal cavity. In the two latter figures may likewise be seen the commencement of the tentacula (*a*) and ovarian septa (*b*), which are all formed by the same process of involution*.

Fig. 37.



(173.) The perigastric spaces of the Actiniæ enclose, in addition to the reproductive apparatus, abundant convolutions of very remarkable filiform organs of great length and tenuity (fig. 38), concerning the nature of which much diversity of opinion still exists. These convoluted threads have, in fact, no communication whatever with the generative organs; they seem to consist of long, semi-capillary cæcal tubes, attached by a short mesentery to the lower margin of the perigastric septa; and from each of them a cord, slightly larger than the filament from which it is

Fig. 38.



Convoluted filiform organs of *Actinia*.

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* "Observations on the Anatomy of Actinia," by T. Spencer Cobbold, M.D., Annals of Nat. Hist., Feb. 1853.

derived, may be traced upwards along the corresponding septum as far as a little above the inferior termination of the alimentary cavity, and then running along the external wall of the stomach as far as the pyloric opening. The structure of the terminal portion as well as that of the convoluted filament is tubular, and their office apparently important in the economy of the animal: M. de Blainville regards them, with some probability, as representing the biliary system.

(174.) The Abbé Dicquemare relates several curious experiments on the multiplication of these animals by mechanical division. When transversely divided, the upper portion still stretched out its tentacles in search of food, which, on being swallowed, sometimes passed through its mutilated body, but was occasionally retained and digested. In about two months, tentacles grew from the cut extremity of the other portion, and this soon afterwards began to seize prey. By similar sections he even succeeded in making an animal with a mouth at each end.

(175.) After the account above given of the general structure of the Actinia, the mechanism whereby the tentacula are expanded and withdrawn will be easily understood: these do not, like the horns of a snail, become inverted and rolled up within the body, but owe their different states of extension entirely to the forcible injection of water into their interior. We have seen already that the cavity of each tubular arm communicates freely with the space intervening between the stomach and the external integument—a space which, at the will of the animal, is filled with sea-water drawn through the orifices placed at the extremity of each arm: when these minute orifices are closed, and the body of the creature contracted, the water, being violently forced into the tentacula, distends and erects them, as when watching for prey; and, on the other hand, when emptied of the fluid thus injected, they shrink and collapse. This circumstance, so easily seen in the Actiniæ, will likewise enable us to account for similar phenomena observable in other polyps, the internal economy of which is by no means so conspicuous.

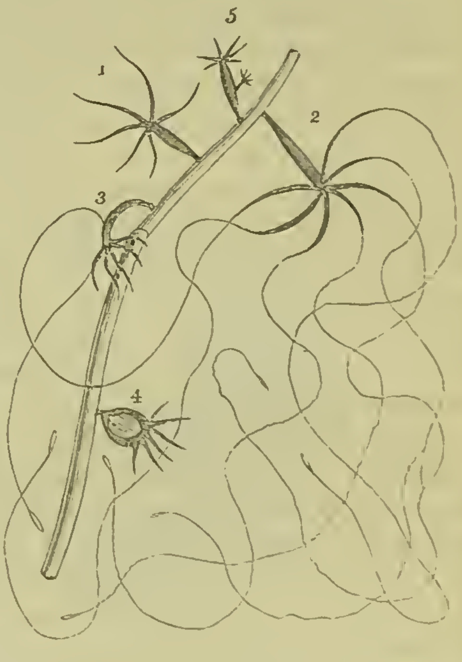
(176.) On cutting off a portion of one of the arms of an Actinia and subjecting it to pressure, it is seen to have, imbedded in the substance of its gelatinous parietes, an immense number of minute organs, now universally known by the name of *filiferous capsules*. These remarkable structures, which are found to exist very extensively throughout the entire group of polypoid organisms, consist of minute sacculi, wherein may be perceived a slender and highly elastic filament coiled up spirally, but which, on compression, suddenly shoots forth from one extremity of the capsule to a length that is perfectly surprising. It is upon the presence of these filiferous capsules that the adhesive power of the tentacula is supposed to depend; and from the rapidity wherewith prey, when seized, is destroyed by their grasp, it is probable that a poisonous fluid is emitted along with the thread, to the virulence of which its paralysing effects are to be attributed. The presence of these remarkable organs is, however, by no means restricted to the tentacula; on the contrary, they are dispersed over various parts of the body, and exist even in the folds of the ovarian membrane. In the latter situation, indeed, they are frequently extremely numerous, and comparatively of large size.

CHAPTER V.

HYDROZOA.

(177.) The Hydræ, or freshwater polyps, are common in the ponds and clear waters of our own country; they are generally found creeping upon confervæ or submerged twigs, and may readily be procured in summer for the purpose of investigating the remarkable circumstances connected with their history.

Fig. 39.



(178.) The body of one of these simple animals consists of a delicate gelatinous tube, contracted at one extremity, which is terminated by a minute sucker, and furnished at the opposite end with a variable number of delicate contractile filaments, placed around the opening that represents the mouth.

(179.) When the Hydra is watching for prey, it remains expanded (fig. 39, 1, 2, 5), its tentacula widely spread and perfectly motionless, waiting patiently till some of the countless beings that populate the stagnant waters it frequents are brought by accident in contact with it: no sooner does an animal touch one of the filaments than its course is arrested as if by magic; it appears instantly fixed to the almost invisible thread, and in spite of its utmost efforts is unable to escape; the tentacle then slowly contracts, and others are brought in contact with the struggling prey, which, thus seized, is gradually dragged towards the orifice of the mouth, that opens to receive it, and slowly forced into the interior of the stomach.

(180.) To the earlier observers of the habits of the Hydra nothing could be more mysterious than this faculty, possessed by the creature, of seizing and retaining active prey, in spite of all its efforts at resistance, but which is now satisfactorily explained as depending upon the presence of a prehensile apparatus, allied in its nature to the filiferous capsules of the *Actiniæ,* described in the last chapter. These wonderful organs are not only thickly dispersed over the whole surface of the tentacles, but are likewise met with, though less numerously distributed, over the general surface of the body. They appear, under high powers of the microscope, to be composed of minute oval vesicles, from each of which can be protruded a long delicate filament, having its free extremity slightly swollen, and apparently of a soft viscid texture, the whole being not inaptly compared by Agassiz to a *lasso.* The neck of each vesicle is furnished with three recurved hooklets, which, when the skin of the animal is irritated, or when the arms are prepared to seize prey, remain erect and prominent. The *modus operandi* of these structures is as simple as the result is efficacious: the "*lasso-threads,*" with their viscid extremities, speedily involve the victim seized, in their tenacious folds, and closely bind it against the hooklets wherewith the surface of the tentacula is thickly studded: these, probably, in their turn constitute prehensile organs, and moreover form an apparatus of poison-fangs of a very deadly character; for it is observable that an animal once seized by the Hydra, even should it escape from its clutches, almost immediately perishes.

(181.) Arrived in the stomach of the polyp, the animal that has been swallowed is still distinctly visible through the transparent body of the Hydra, which seems like a delicate film spread over it (fig. 39, 4); gradually the outline of the included victim becomes indistinct, and the film that covers it turbid; the process of digestion has begun: the soft parts are soon dissolved and reduced to a fluid mass, and the shell or hard integument is expelled through the same aperture by which it entered the stomach.

(182.) No traces of vessels of any kind have as yet been detected in the granular parenchyma of which the creature is composed; coloured globules are seen floating in a transparent fluid, which, in the *Hydra viridis,* are green, although in other species they assume different tints. When the food has been composed of coloured substance, as, for example, red larvæ, or black *Planariæ,* the granules of the body acquire a similar hue, but the fluid wherein they float remains quite transparent; each granule seems like a little vesicle into which the coloured matter is conveyed, and the dispersion of these globules through the body gives to the whole polyp the hue of the prey it has devoured; sometimes the granules thus tinted are forced into the tentacula, from whence they are driven again by a sort of reflux into the body, producing a kind of circulation, or rather mixing up, of the granular matter, and distributing it to all parts. If, after having digested coloured prey, the polyp is made to fast for some time, the vesicles gradually lose their deepened hue and become comparatively transparent. The granules, therefore, would seem to be specially connected with the absorption and distribution of nutriment.

(183.) When mature and well supplied with food, minute gemmules or buds are developed from the common substance of the body; they spring from no particular part, but seem to be formed upon any portion of the general surface. These gemmæ appear at first like delicate gelatinous tubercles upon the exterior of the parent polyp; but as they increase in size they gradually assume a similar form, become perforated at their unattached extremity, and develope around the oral aperture the tentacles characteristic of their species.

(184.) This mode of propagation, termed "gemmation," differs from the development of the Hydra *ab ovo*, inasmuch as the germ-cell. which sets on foot the process, is derivative and included in the body of the adult, instead of being primary and included in a free ovum.

(185.) Sometimes six or seven gemmæ have been observed to sprout at once from the same Hydra; and although the whole process is concluded in twenty-four hours, not unfrequently a third generation may be observed springing from the newly-formed polyps even before their separation from their parent: eighteen have in this manner been seen united into one group; so that, provided each individual, when complete. exhibited equal fecundity, more than a million might be produced in the course of a month from a single polyp.

(186.) But perhaps the most remarkable feature in the history of the Hydra is its power of being multiplied by mechanical division. If a snip be made with a fine pair of scissors in the side of one of these creatures, not only does the wound soon heal, but a young polyp sprouts from the wounded part; if it be cut into two portions by a transverse incision, each speedily developes the wanting parts of its structure: if longitudinally divided, both portions soon become complete animals; if even it be cut into several parts, every one of them will in time assume the form and functions of the original.

(187.) It has recently been discovered that the *Hydræ*. at certain seasons of the year, are reproduced from real ova*, at which period various observers have proved them to be possessed of a male apparatus of a most remarkable character. This strange organism makes its appearance under the form of two, three, or four minute conical tubercles, which become developed from the sides of the body, at a short distance below the tentacula; and in these, under the microscope, a glandular-looking body and innumerable active particles are seen to be contained.

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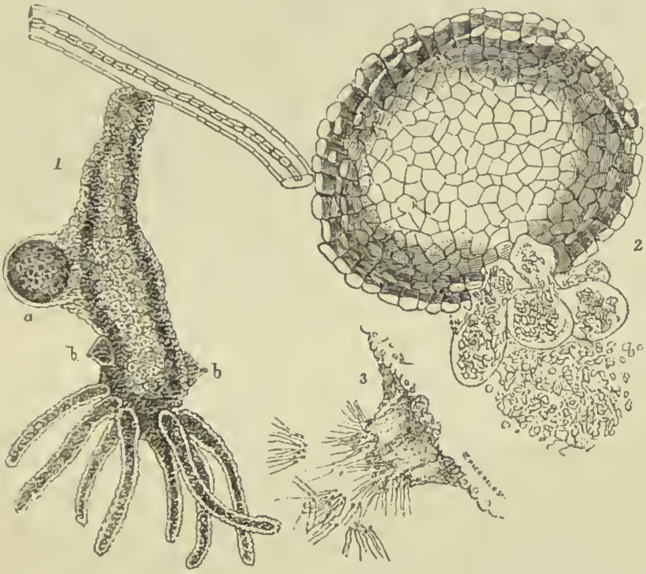
* "On a species of *Hydra* found in the Northumberland Lakes," by A. Hancock. Esq., Ann. and Mag. of Nat. Hist. for 1850.

(188.) The conical eminences, which constitute the spermatic capsules, appear to derive their origin from the greater degree of development of one or more of the superficial cells in the vicinity of the base of the arms. These capsules sometimes occur in considerable numbers, as from eight to sixteen, on the brown polyp; but in the green species only two or three are generally seen, placed on opposite sides of the body, and invariably situated somewhere in the vicinity of the oral extremity (fig. 40, 1, *b b*). The interior of the capsules has a slightly ribbed or striated appearance; and at the summit a small aperture is sometimes perceptible, through which, when the development is complete, the spermatic filaments are observed to issue. On breaking up the capsule, under the microscope, large numbers of these filaments are seen united in bundles by their minute globular heads, the filamentous part being free, and vibrating with great rapidity in the manner which is known to be characteristic of these bodies in all animals (fig. 40, 3). These spermatic capsules were observed by Dr. Allen Thompson* on many individuals in which no ova existed. The ova are developed in the lower portion of the body, which, at the time when the male apparatus makes its appearance, becomes considerably enlarged, presenting an opake swelling, in the interior of which an ovum makes its appearance

Fig. 40.



Oviparous reproduction of Hydra viridis. 1. Body of Hydra magnified: *a*, the ovum contained in the ovigerous capsule sprouting from the side of the polyp; *b*, *b*, spermatic capsules. 2. Mature ovum of Hydra crushed, its contents escaping. 3. Spermatic capsule broken by pressure, showing the contained spermatozoa.

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* Edinburgh New Philosophical Journal, 1846.

(fig. 40, 1, *a*); when mature, this ovum becomes detached from the parent animal and fixes itself to some foreign body.

(189.) The ovigerous capsule is, when fully developed, of such a size as to be seen with the naked eye. It is attached to the side of the polyp, nearer to the foot than the spermatic capsules, and is distinguished from the rest by its spherical form and yellowish-brown colour. In the *Hydra viridis* only one of these ova appears to be developed on the body of the polyp at the same time; but a number, varying from five to seven, have been occasionally observed upon the *Hydra fusca.*

(190.) The ovum appears, at first, as a small granular mass in the thickness of the wall of the animal. As the spherical yelk-mass enlarges, it projects from the side, seeming to carry along with it the outer or clearer layer of the animal's body; then the cells of this layer grow thinner, and recede from the outer covering or capsule enveloping the egg-like mass, which at the same time becomes much thicker, and is left attached to the animal only by a narrow portion or pedicle. As the development proceeds, a similar atrophy of the cells of the pedicle is followed at last by the separation of the spherical mass, which is thus detached from the parent polyp.

(191.) From various observations it would seem that while some of the individuals of the *Hydræ* are hermaphrodite, others produce the organs of one sex only; but generally both kinds are developed from the same Hydra.

(192.) The fertilization of the ova cannot take place until after the rupture of the spermatic cyst and that of the ovisac also; so that the parent has no more participation in it than has the *Fucus* in the analogous fertilization of its germ-cells after their discharge. Although the production of a new Hydra from such an egg has not yet been witnessed, there seems no reason to doubt the fact. It would seem that this alternation of reproduction between the gemmiparous and the sexual is greatly influenced by temperature, the eggs being produced at the approach of winter and serving to regenerate the species in the spring. while the budding process naturally takes place only during the warmer seasons of the year, but may be made to continue through the whole by a sufficiently high temperature.

(193.) Nearly related to the *Hydræ* is the remarkable group of *Gelatinous Polyps,* as they are named by Cuvier in his classification of the Animal Kingdom, constituting the genus CORYNE (*Corine* of Gaertner). One of these little animals, seen with the naked eye, observes Mr. Gosse*. to whom we are indebted for the following particulars of their history. looks like a very slender branching plant. It is altogether about as thick as fine sewing-cotton, creeping along a frond of sea-weed, or other substance upon which it grows, like an irregularly-winding thread. This creeping root sends off frequent rootlets, which, crossing each other.

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* Rambles on the Devonshire Coast. 1853.

appear to anastomose, making a sort of network from which free stalks shoot up here and there, sometimes to the length of three inches or more, sending forth the polyp-branchlets irregularly on all sides. The creeping fibre, the stalk, and the branchlets are seen under the microscope to be tubular; and the two latter are marked throughout their course with close-set rings or false joints, apparently produced by the annular infolding of a small portion of the integument. The tube is of a yellowish-brown colour, sufficiently translucent to reveal a core or central axis of flesh running along its centre and sending off branches into the polyp-branchlets, from the open lips of which the flesh emerges in the form of a thickened oblong head, somewhat club-shaped, whence the name *Coryne* (from *κορύνη*, a club). The tube or sheath becomes membranous, or rather gelatinous, at its margin, the ultimate three or four rings being evidently soft and scarcely consistent, of undefined outline, and larger than the rest. The club-shaped head of the polyp is studded with short tentacles, of curious and beautiful structure. These vary much in number in each polyp; but the full complement appears to be from twenty-five to thirty, arranged somewhat in a whorled manner in four or five whorls, which, however, especially the lower ones, are often irregular and scarcely distinct. The tentacles spring from the axis, with a graceful curve; they are rather thick and short when contracted, but slender when elongated, and nearly equal in diameter, except at the termination, where each is furnished with a globose head studded all over with tubercles, each of which is tipped with a minute bristle. The neck or body of the tentacle is perfectly transparent, and appears to be a tube with thin walls, but containing a colourless thickish axis freely permeating its centre, marked with delicate parallel rings. The tentacles are endowed with the power of free motion, and they frequently throw themselves to and fro with considerable energy. The whole polyp likewise can be tossed together from side to side at pleasure.

(194.) TUBULARIDÆ.—In the Tubular Hydrozoa the structure of the tentacula is widely different from what has been described in *Tubipora musica* and other anthozoic polyps. When the Tubularia is expanded, its protruded portion is seen to be furnished with two circles of arms, one placed around the opening of the mouth, the other at a considerable distance beneath it (fig. 41, 1); and, nearly on a level with the inferior circle, a second aperture (fig. 41, 1, *a*) is observable, communicating with that portion of the body which is lodged within the tube, and resembling a second mouth. A remarkable action has been observed to take place in these parts of the polyp, producing a continual variation in their form*: a fluid appears, at intervals, to be forced from the lower compartment into the space intervening between the two rows of tentacula, which becomes gradually dilated into a globular form (fig. 41, 2, 3).

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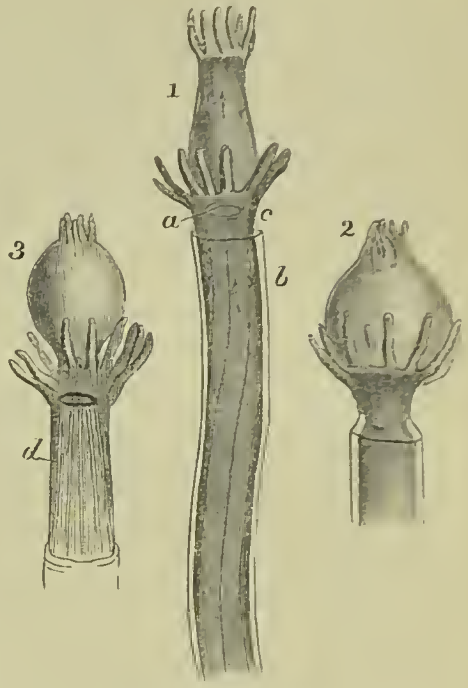
[*] Lister, "On the Structure and Functions of Tubular and Cellular Polypi," Phil. Trans. 1834.

This distension continues for about a minute, when the upper part, contracting in turn, squeezes back the fluid which fills it into the lower compartment through the opening *a*, which then closes preparatory to a repetition of the operation. The intervals between these actions were, in the specimen observed by Mr. Lister, very evenly eighty seconds. In *Tubularia indivisa* the sheath or cell, *b*, which encloses the polyp is perfectly diaphanous, allowing its contents to be readily investigated under the microscope. When thus examined, a continual circulation of particles is visible, moving in even, steady currents in the direction of the arrows (fig. 41, 1) along slightly spiral lines represented in the drawing. The particles are of various sizes, some very minute, others apparently aggregations of smaller ones; some are globular, but they have generally no regular form.

Fig. 41.



Tubularia indivisa.

(195.) The mode of propagation in *Coryne, Tubularia,* and other genera of Hydriform polyps has occupied the attention of many diligent inquirers, the results of whose labours are extremely interesting and important; it is, however, to the researches of Professor Van Beneden that science is principally indebted for information upon this subject. According to the observations of that indefatigable naturalist*, the reproduction of these zoophytes is effected in no fewer than three different ways:—

1. By continuous gemmation.
2. By the production of free gemmæ.
3. By simple ova.

(196.) Observation has moreover shown that in every species propagation is effected by more than one of these modes of reproduction, and sometimes by three or four; and it must be remarked that in none of them is the cooperation of a male apparatus requisite, neither have any male organs or spermatozoa been as yet detected.

(197.) *Development by continuous gemmation* is the simplest possible.

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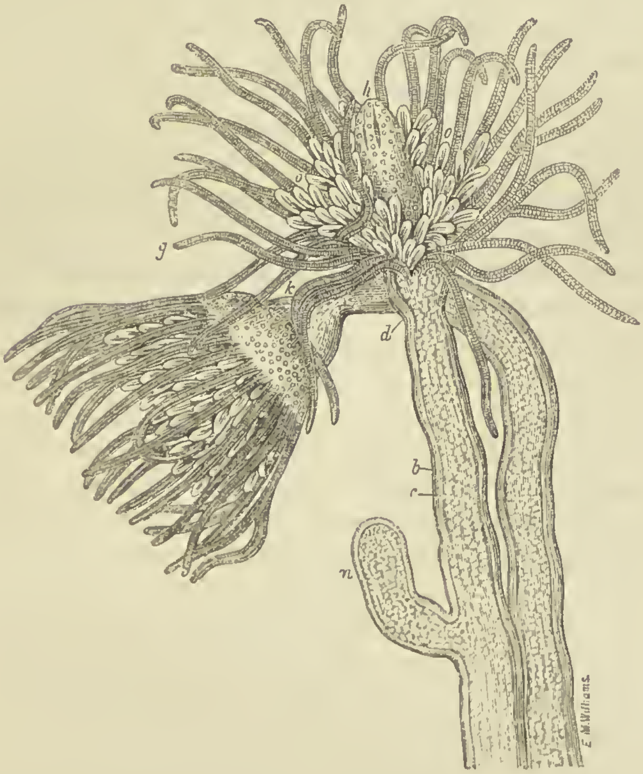
* Nouveaux Mémoires de l'Académie de Bruxelles, 1843–1844.

and is effected by mere growth from the original polyp at certain determinate points of its substance, which points are similarly situated with respect to each other in all the individuals belonging to the same species. At these points appear gemmæ exactly similar, both in texture and mode of growth, to the body from which they spring; and the buds thus produced give birth to others in a precisely similar manner.

(198.) In like manner when a stem is cut off transversely, a bud is developed from the cut extremity, which by its growth prolongs the original trunk. When this kind of gemma has attained to a sufficient size, there arises from its extremity a little crown of tubercles; subsequently a second becomes manifest, at some distance from the first; and as the growth of these tubercles continues, each of them becomes at length developed into a tentacle. The tentacle, therefore, grows from the body exactly in the same way as the bud from the stem, the only difference being that the former is solid, and the latter tubular.

(199.) The growth of the horny sheath of the polypary (fig. 42, *b*) exactly keeps pace with the development of the soft substance, and even advances beyond it.

Fig. 42.



Tubularia coronata. *b*, the polypary, or horny sheath; *c*, living substance of the animal; *d*, boundary between the individual and the common stock; *g*, tentacular arms; *k*, tentacular zone; *h*, mouth; *n*, reproduction by continuous gemmation; *o*, ovigerous capsules. (After Van Beneden.)

(200.) Below the tentacula the body of the polyp appears constricted, marking the boundary between it and the stem; and soon the flower-like head, becoming too large to be contained in its sheath, issues forth, and, expanding its tentacula, displays itself perfectly unfolded (fig. 42, *g*, *h*). The ovigerous pedicles, *o*, hereafter to be described, are developed subsequently.

(201.) *Second mode of propagation, by free gemmæ.*—The free gemmæ are produced upon distinct pedicles, which in the genus *Tubularia* are developed within the lower circle of tentacula. They resemble numerous appendages disposed in a circle, and forming a crown around the body of the polyp (fig. 42, *o*). These pedicles grow in the same manner as the buds and the tentacula described above; that is to say, a hollow tubercle first makes its appearance, which seems to be merely an extension of the external covering of the polyp. Each tubercle slowly expands, and soon divides into one or more branches, which are all hollow, and the same fluid that circulates in the general substance of the polyp may be observed to pass into their interior (fig. 44, A′).

(202.) At the free extremity of each of the pedicles thus formed, a distinct cell is soon perceptible (fig. 43, A, B, C, *a*), situated immediately beneath the surface, which cell is the rudiment of a new individual. No nucleus has been remarked in its interior. This primitive cell may be regarded as the analogue of the vitelline sac, or, perhaps, as the vesicle of Purkinje or of Wagner; most probably, however, it is the vitelline vesicle, from the circumstance that it becomes organized internally, in which case the reproductive process assumes the third or the fourth form, subsequently to be noticed; or else it serves for the point of departure, or, it might almost be said, the mould for the formation of a free gemma, which becomes organized around it at the expense of the pedicle itself. It is, in effect, a part of the reproductive appendage that will subsequently become detached; but at this period of its development it is impossible to determine after which of the four modes of reproduction the embryo will be formed. The vesicle (fig. 43, A, B, C, *a*) now increases rapidly in size, and beneath it another membrane (fig. 43, A, B, C, *b*) is soon perceptible, which by its inner surface is in contact with the circulating fluid. This membrane is the origin of the new individual; or, in other words, it is a blastoderm, formed by the internal skin, and not by the vitellus. Soon there is seen, projecting from its centre, a little cone (fig. 43, B, *b*) which, compressing the vesicle, *a*, forms a depression upon its inferior surface, so that the vesicle begins to assume the appearance of a serous membrane, yielding to the pressure of the organs over which it spreads, and which it ultimately covers much in the same way as the pleura covers the lungs. The tubercle, *b*, will afterwards form the walls of the digestive cavity of the new animal, and may be seen to have a circulating fluid, derived from the body of the polyp, moving in its substance. Around the base of the cone, *b*, may now be seen four other tubercles (fig. 43, c, *c*), which become developed like the preceding; but instead of compressing the vesicle, *a*, they surround it, and ultimately completely enclose it. They are united together by a thin membrane, so as to present the appearance of a transparent vase, having four longitudinal prominent bands, the free edge slightly enlarged and rounded, a pedicle in the middle like the stem of the vase, and the transparent vesicle lining its interior throughout (fig. 43, E).

(203.) The different phases of the mode of development above described, however, will be best understood by a reference to the series of figures which we have appended, carefully copied from Professor Van Beneden's elaborate illustrations.

(204.) The young Tubularia has now assumed the appearance of a Beroë, and in this condition has doubtless been often mistaken for an individual belonging to the class Acalephæ, to be described in the next chapter; lively contractions of its body are frequently witnessed, although it still remains attached to its pedicle.

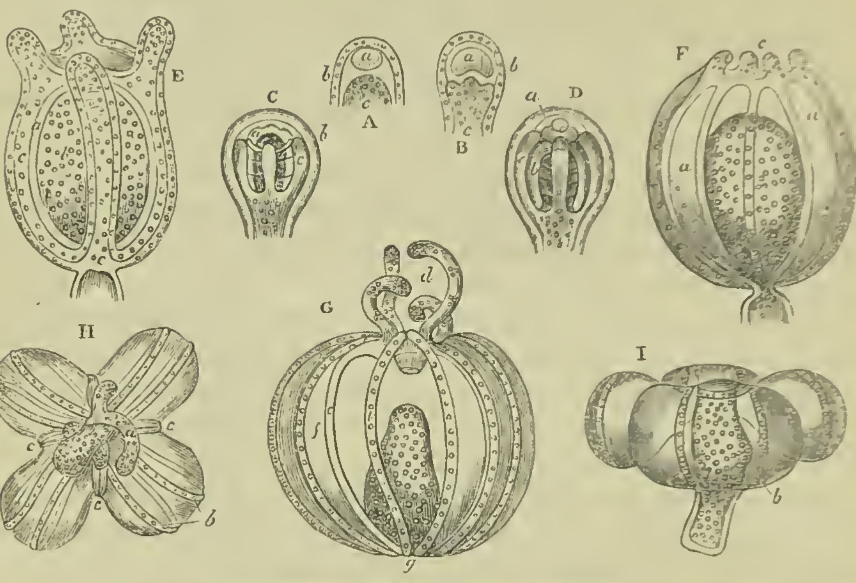
(205.) At the extremity of each of the four longitudinal vessels a little tubercle is next developed (fig. 43, F, *e*), which, as it becomes elongated, is converted into a tentacle; or sometimes, as in *Eudendrium*, by its bifurcation, two tentacula are formed from each tubercle.

(206.) At this period of its development the young Tubularia spontaneously detaches itself from the parent stem, presenting, at the moment of its separation, the appearance of a balloon, or rather, of a melon (fig. 43, G). Its contractions become more and more lively; and it is by the aid of these movements that its separation is effected. The two poles of its globular body may be seen to approach each other, and to separate alternately with a movement of systole and diastole, similar to what is observable in many Acalephæ. No traces of cilia are observable either externally or in the interior of its body. In this condition it presents an external covering, which is, so to speak, merely a derivation from the integument of the parent-polyp; this covering presents somewhat more consistence than the internal parts, and is open in front.

(207.) A second membrane lines the preceding throughout its whole extent; like the former it is quite transparent, and at the anterior opening is prolonged internally to a little distance, forming a sort of funnel. These walls enclose four vessels (fig. 43, H, *c*), which extend from the base of the embryo, and open in front into the hollow zone from which the tentacula take their origin. These longitudinal vessels, therefore, communicate with each other by a transverse canal, and at their origin open into the central or digestive cavity. From this disposition it results that the contents of the stomach can pass as far as the extremities of these four vessels, and by means of the transverse canal can be transferred from one to the other. Professor Van Beneden observed a fluid containing globules moving in this direction in their interior.

The communication by means of transverse canals is another arrangement exactly similar to what exists in the adult Beroëform Medusæ.

Fig. 43.



Development of *Tubularia* by free gemmæ.

(208.) The outer membrane presents eight longitudinal canals (fig. 43, G, H, *b*), which are found to be filled with cellules, but in which no movement has been observed. It is to the presence of these longitudinal bands that the embryo in this stage of its development owes its resemblance to certain fruits, more particularly to a melon.

(209.) From the anterior part proceed four appendages (fig. 43, G, *d*), which were still undeveloped at the period of the detachment of the young polyp, but now insensibly unfold themselves. These are the tentacula. In the centre there projects a rounded opake body, generally of a red or yellowish tinge, which is the stomach. This viscus communicates, as has been stated above, with the four longitudinal vessels, and is the only opake part of the embryo. It opens in front by an orifice that constitutes the mouth; the whole organ is eminently contractile, turning in all directions like the body of a Hydra, sometimes elongating itself like a worm, and at others shrinking so as to be almost imperceptible.

(210.) If the embryos examined in this condition be vigorous, their movements are very varied, and the forms that they assume extremely singular. The regular contractions above noticed are the most simple actions; the two poles separate and approach each other alternately, whence results the progression of the little creature. But this contraction may be carried to a still higher degree: the rounded stomach in the middle of the embryo not only moves itself about in every direction, but it seems to make efforts in the middle of its transparent envelope, like a worm in search of a passage by which to get out; and at length it pushes its free extremity through the opening in front of it, and elongates its body still more, until the two poles of the balloon getting approximated, the whole embryo becomes somewhat disk-shaped, or the four vessels that communicate with the stomach (if vessels they really are), by moderately contracting, form as many depressions dividing the disk into four lobes (fig. 43, H, I), or by a more forcible contraction give it the appearance of a Greek cross; and all these changes of form may take place in a few seconds.

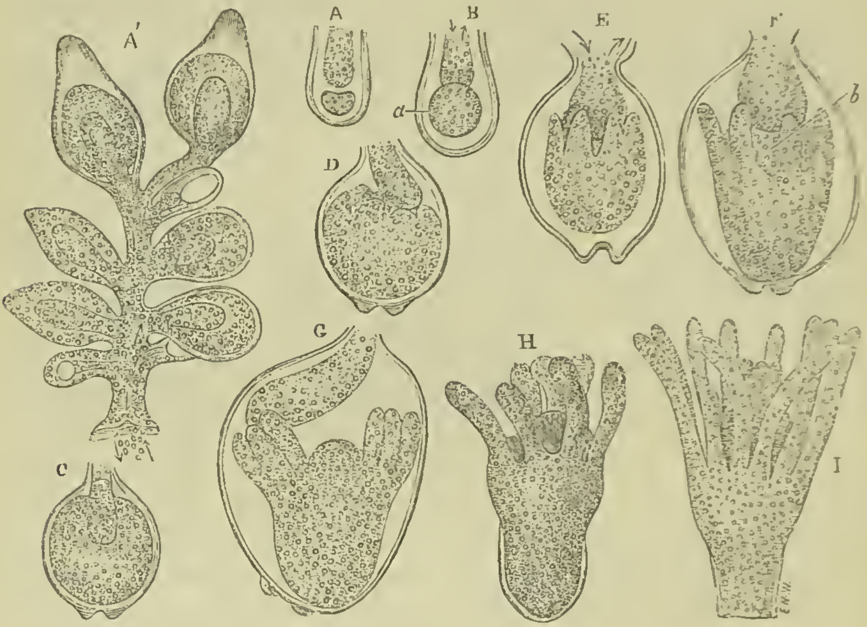
(211.) Observations are wanting relative to the manner in which the free acaleph gives origin to the fixed polyp; for although Professor Van Beneden observed the latter at a very early period after they had become attached, he was unable to witness any further changes that they undergo, and therefore gives a hypothetical outline of the forms through which he supposes them to pass, preparatory to their final establishment as young Tubulariæ.

(212.) *Third mode of propagation, by simple ova.*—This mode of reproduction approximates the nearest to what occurs in the higher animals. Cells are observed in process of gradual organization in the middle of a vesicle, in the same manner as the vitelline cells, which are converted into an embryo. In this case the vitelline cells become aggregated and modified, so as to give rise to a new individual, which is isolated from the commencement of its existence. The point of departure for the formation of the embryo is the same as in the preceding mode of development, and the reproductive vesicle has at first precisely the same structure; but instead of preserving its transparency, this vesicle soon exhibits numerous cells, which render it more and more opake, and give it the appearance of a vitellus. In this case, moreover, there is a great difference in the relations which the red pedicle (fig. 44, A, B), bears to the embryo. In the preceding mode of development this pedicle constitutes an integrant part of the newly-formed being, forming, in fact, its stomach; but in the oviparous mode, there is no organic connexion between the one and the other, the vitellus being formed between the pedicle and the integument of the offset, and on pressing the latter between two plates of glass, these structures readily separate without any laceration.

(213.) As the vitellus (fig. 44, B, *a*) increases in size, it becomes impacted between the integument and the pedicle, and its augmentation of bulk still increasing, the upper part of the pedicle becomes covered with it as with a hood, and at last almost entirely enveloped by it (fig. 44, C, D, E). At this period the margins of the vitellus become indented on that side nearest the pedicle, and the tubercles between the indentations soon show themselves to be the rudiments of tentacula. The tentacula become more and more elongated, the embryo separates itself slightly from the pedicle, and a protuberance (fig. 44, F, G, *b*) is then perceived in the centre of the tentacular zone, which becomes the proper body of the polyp, or rather, forms the walls of its stomachal cavity.

(214.) The walls of the bud which has hitherto contained the embryo now become ruptured, and it gains its liberty (fig. 44, H). In this condition it almost exactly resembles a young Hydra in its contracted state; and, in fact, both its body and its tentacula seem to have the same anatomical structure as those of that simply organized polyp. Having attained to this condition, its development proceeds rapidly, and it soon begins to assume the specific form of the Tubularia from which it sprung (fig. 44, I).

Fig. 44.



Development of *Tubularia* from ova.

(215.) Sertularidæ.—In the Sertularian Hydrozoa, the fleshy substance of the animal is enclosed in a ramose horny sheath, which it traverses like the pith of a tree, following all the ramifications of the branched stem of the polypary.

(216.) Zoophytes of this description are readily found on our own coasts, and the microscopic observer can scarcely enjoy a richer treat than the examination of them affords. In order to study them satisfactorily, it is necessary to be provided with several glass troughs, of different depths, in which the living animals immersed in their native element may be placed: in this situation, if the water be carefully renewed at short intervals, they will live for some time.

(217.) Besides the cells which contain the polyps, others, specially destined to the development of the ova, exist at certain periods of the year; they are larger than the preceding, and of a very different shape: but of these we shall have occasion to speak more fully hereafter.

(218.) The general stem of the polypary is entirely filled with a fleshy substance exactly resembling in its nature the tissue composing the body of the polyp, whereby all the individuals belonging to the common stock are brought into communication with each other. Internally it seems to be hollow, and to contain a fluid, in which numerous globules may be observed in active motion. It is from this central fleshy substance that the buds or lateral offsets derive their origin.

(219.) On examining attentively the stem of a living Sertularia, the globules are all seen to follow each other in distinct currents, and sometimes may be observed to move in opposite directions in the same branch: on arriving at the bifurcation of a stem, some seem to stop, whilst others continue their course to the right or left. If the branch of a living polypary, while in a state of activity, be divided and slightly compressed, the globules that escape from the cut extremity still continue their movements for some considerable time, somewhat after the manner of zoosperms; and as this kind of motion, when observed externally to the polypary, resembles very closely that which they exhibit in its interior, it is apparently not dependent upon any pressure from the walls of the general fleshy substance, but seems to be inherent in the globules themselves. The general movement of the fluid contained in a branch, however, more especially as relates to its direction, depends upon the pressure exercised by the polyps; so that if several individuals on one side of a branch contract simultaneously, they sometimes even force the contained liquid through the mouths of those upon the opposite side.

(220.) It has been generally stated that the living pith exudes from its surface the horny matter which, by its concretion, forms the tube or external skeleton investing the whole; the accuracy of such a supposition, nevertheless, may well be questioned. We have already seen, in the *Tubipora musica*, that the calcareous tube investing that polyp was produced by the interstitial deposits of earthy matter in the membrane that originally constituted its outer case. In the tribe of zoophytes we are now speaking of, we shall find the exterior tube to be formed in a way precisely similar. On referring to the diagram (fig. 45), the mode of its growth will be rendered intelligible. The soft part, or living axis of the polypary, is seen to be contained in two distinct layers: the inner one, *a*, being continuous with the digestive sac of the polyp, and immediately embracing the granular matter, seems to be the special seat of the nutritive process; the outer or tegumentary layer, *b*, after leaving the tentacula, may be traced down the sides of each polyp to the bottom of the cell, where its course is arrested by a slight partition, at which point it turns outwards, lining the interior of the cell as far as its margin, where, as in the Tubipora, it is seen to be continuous with the horny matter itself. It is this tegumentary membrane, then, which forms by its development the entire skeleton.

As it expands, it gives origin to the cells and branches characteristic of the species; and, from being at first quite soft and flexible, it gradually acquires hardness and solidity by the deposition of corneous matter in its substance.

Fig. 45.

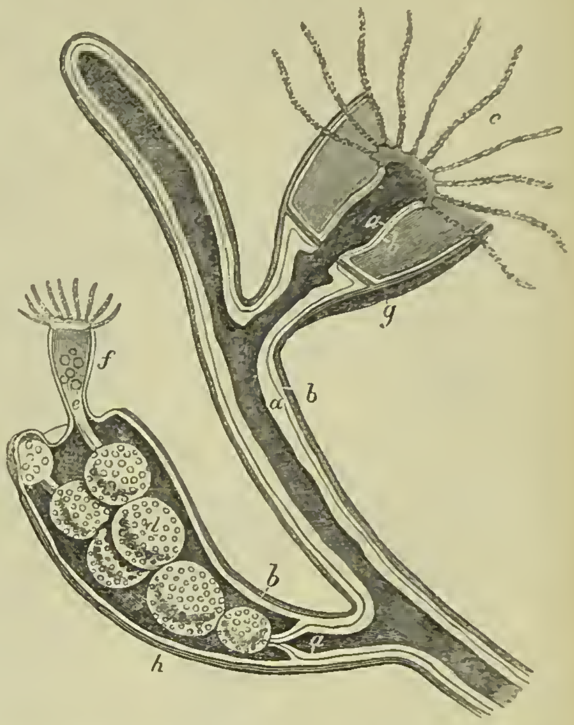


Diagram representing section of a Sertularian zoophyte. *a*, inner or nutritive layer; *b*, outer or tegumentary layer; *c*, oral tentacles of the polyp; *d*, *e*, gemmules; *f*, polypiform external capsule; *g*, polypiferous cell; *h*, reproductive cell.

(221.) The cells thus formed are inhabited by polyps analogous to those that provide nourishment for the cortical families, though differing in the number and appearance of the tentacula, which are here studded with minute tubercles, but never provided with cilia. Few objects are more admirable than these polyps, when watched with a good microscope. Protruding themselves beyond the mouths of their cells, they inflect their bodies in all directions in quest of prey, waiting till some passing object impinges upon their tentacula, when it is at once seized and conveyed into the stomach with a rapidity and dexterity almost beyond belief.

(222.) The tentacula in the Sertularian Hydrozoa are all arranged in a single row, and form a sort of funnel-like appendage to the oral orifice of the body. They are susceptible of considerable elongation and contraction, like those of the Hydra, but in a less degree. Their number is constant throughout the different periods of growth in each species, but varies in different genera. Internally they are not hollow as is the case in the Anthozoa, but under the microscope they have the appearance of being divided into compartments by delicate transparent diaphragms, giving them an appearance like that of some Confervæ: they are throughout of equal thickness, and no movement of fluids is perceptible in their interior.

(223.) In the centre of the tentacular circle may be observed a fleshy protuberance of variable shape, which might be compared to a proboscidiform elongation of the mouth; sometimes this appendage is elongated into the form of a tube, sometimes it shrinks into a globular mass, or occasionally it may be seen so completely contracted as simply to form a broad lip-like ring around the oral opening.

(224.) The stomach, as in the Hydra, is a simple cavity excavated in the interior of the body, without any proper parietes, which inferiorly communicates immediately with the fleshy substance contained in the common polypary; so that the contents of the stomachal sac may not unfrequently be seen to pass into the living pith, and in like manner the globules there circulating to return into the stomach.

(225.) The multiplication of these beautiful zoophytes appears to take place in three different modes:—1st, by cuttings, as in plants; 2ndly, by offshoots, or the formation of new branches bearing polyps; 3rdly, by *Planulæ* capable of locomotion.

(226.) The first mode strikingly resembles what is observed in the vegetable kingdom; for, as every branch of the plant-like body contains all the parts necessary to independent existence, it can hardly be a matter of surprise that any portion, separated from the rest, will continue to grow and perform the functions of the entire animal.

(227.) The second mode of increase, namely, by the formation of new branches and polyps, seems more like the growth of a plant than the development of an animal. We will consider it under two points of view:—first, as regards the elongation of the stem; secondly, as relates to the formation of fresh cells containing the nutritive polyps. On examining any growing branch, it will be found to be soft and open at the extremity, and the soft tegumentary membrane (above described as forming the tube by its conversion into hard substance) is seen to protrude through the terminal orifice; the skeleton is therefore not merely secreted by the enclosed living granular matter, but it is the investing membrane, which continually shoots upwards, and deposits hard material in its substance as it assumes the form and spreads into the ramifications peculiar to its species.

(228.) Having thus lengthened the stem to a certain distance, the next step is the formation of a cell and a new polyp, which is accomplished in the following manner*. The newly-formed branch has at first precisely the appearance and structure of the rest of the stalk of the zoophyte (fig. 46, 1), being filled with granular matter, and exhibiting in its interior the circulation of globules (already described)—moving towards the extremity along the sides of the tube, and in an opposite course in the middle; the end of the branch, however, before soft and rounded, soon becomes perceptibly dilated. After a few hours the branch is visibly longer, its extremity more swollen, and the living pith is seen to have partially separated itself from the sides of the tube, the boundaries of which become more defined and undulating (2). The growth still proceeding, the extremity is distinctly dilated into a cell, in which the soft substance seems to be swollen out, so as to give a rude outline of the bell-shaped polyp (3), but no tentacula are yet distinguishable: a rudimentary septum becomes visible, stretching across the bottom of the cell, through the centre of which the granular matter, now collected into a mass occupying only a portion of the stem, is seen to pass. The polyp and cell gradually grow more defined (4, 5, 6), and the tentacula become distinguishable; the cell, moreover, is seen to be continued inwards by a membranous infundibular prolongation of its margin (7). that immediately reminds us of the funnel-shaped membrane of *Tubipora* (§ 157), and its office is no doubt similar. As the development proceeds, the tentacles become more perfect (8, 9), and the polyp at length rises from its cell to exercise the functions to which it is destined.

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* Lister, Phil. Trans. *loc. cit.*

Fig. 46.

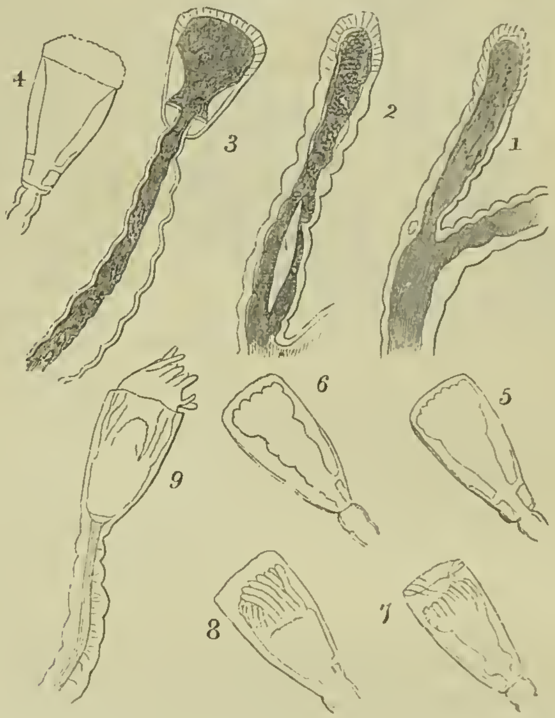

Diagram illustrating the mode of growth of a Sertularian polypidom.

(229.) The main feature that distinguishes the Sertularian Zoophytes from the *Hydræ* seems to consist in the fact that, whereas in the latter each newly-formed offset becomes detached from the parent stock and enjoys a separate existence, in the former each new sprout remains permanently adherent, the successive generations being united into a ramified stem, which is common to the entire group. The Hydra, having no polypary or outer covering, when it dies, entirely perishes: but in the Sertularidæ, every sprout, when it dies, leaves its horny integument attached to the general community; and thus, in time, there results an elaborately-branched stem, the complexity of which increases with the age of the colony.

(230.) The third mode of multiplication, or that by *Planulæ,* seems to be specially adapted to the diffusion of the species; and as it presents many points of peculiar interest, we shall dwell upon it at some length. At certain periods of the year, besides the ordinary cells adapted to contain nutritive polyps, others are developed from different parts of the stem, which may be called female or fertile polyps, although usually simply termed the *vesicles.* The cells of this kind are much larger than the nutritive cells, and of very different form (fig. 48, A); they are moreover deciduous, falling off after the fulfilment of the office for which they are provided. They are produced in the same manner as the rest of the stem, by an extension of the tegumentary membrane (fig. 45, *b*), which, as it expands into the form of the cell, becomes of a horny texture; it may be traced, however, over the opening of the cavity, where it sometimes forms a moveable operculum. The cell being thus constructed by the expansion and subsequent hardening of the tegumentary membrane, it remains to explain the origin of the reproductive germs which soon become developed in its interior.

(231.) According to the observations of Lovén on the reproductive process in *Sertularia,* the first appearance of the reproductive germ is a slight elevation (derived from the central mass contained in the ovarian vesicle), in the centre of which an active circulation of nutritious globules seems to be concentrated. This protuberance gradually enlarges and assumes a spherical form, the part whereby it is attached to the central mass becomes constricted, and at the same time its cavity becomes enlarged, and divided into several compartments.

(232.) Upon the outer aspect of the newly-formed germ a little spherical body may be detected, composed of coloured granular substance, in which a circular transparent spot speedily becomes perceptible.

(233.) A delicate translucent capsule envelopes the parts described above, which, after a time, exhibits at its upper and outer surface a circle of minute elevations. This capsule Lovén regards as the body of a female polyp, of which the little elevations are the rudimentary tentacula; and its contents manifestly constitute an ovum, enclosing a Purkinjean vesicle. Several of these ova are formed in the ovarian vesicle, presenting different degrees of development, the upper ones being the most advanced in growth. In proportion as each ovum increases in size, the original sacculus, which is merely a prolongation of the central living substance of the polypary, and which at first formed the larger part of the germ, becomes proportionally smaller, owing to the rapidly-increasing dimensions of the ovum, and soon the vesicle of Purkinje is no longer discoverable. Meanwhile the canal whereby its cavity communicates with the central mass becomes elongated; so that its union with the common substance of the polypary is not destroyed even when the "*female polyp*" has burst through the external membrane and the thin operculum of the ovarian capsule in which it was formed.

(234.) When the "female polyp" has thus escaped from the ovarian vesicle of the common polypary, it has the appearance of a globular transparent capsule attached by a short pedicle to the operculum through which it has made its way, the orifice whereby it escaped having closed around its stem. The tentacles are twelve in number; and from the circle surrounding their base, four canals may be traced, descending in the substance of the globular body to terminate in the pedicle or sacculus that occupies the lower part of the (Medusiform) capsule.

(235.) On the rupture of the external membrane of the ovum enclosed in the "female polyp," the young animal escapes, under a form not at all resembling that of the parent animal.

(236.) It presents at this period the appearance of a little worm, of an elliptical shape, slightly flattened. Its entire surface is thickly covered with vibratile cilia, by the agency of which it moves about even while still imprisoned in the body of its mother, from which it subsequently makes its escape through the oral orifice. Generally each "female" gives birth to two embryos, occasionally to three.

(237.) No sooner has the young larva got free than it begins to swim about, by means of its cilia, with a uniform gliding motion: sometimes it turns round incessantly upon its axis, either horizontally or in a vertical direction, at the same time varying its shape from that of an egg to that of a pear. It is of a whitish colour, but still sufficiently transparent under the microscope to show that it contains a cavity filled with a coloured fluid, and composed of two membranes, whereof one, the outer, is transparent as glass, the internal slightly opake.

(238.) Repeated observations render it improbable that in this condition the little embryo is nourished by means of a mouth.

(239.) After swimming about for some time in the above condition, the young creature fixes itself to some foreign body, such as a fucus, or other marine production; and then its form begins to be entirely changed, and it is converted into a flat, circular disk, around which the cilia, now quiescent, form a circular transparent fringe. In the centre of its internal cavity an opake round spot makes its appearance, the size of which is about a fifth part of that of the whole body, composed of a mass of granules placed concentrically, and occupying the situation whence the stem of the nascent polypary is to be developed. At this point the external membrane becomes slightly thickened, and, as it were, furrowed with vessels proceeding from the internal cavity. From the opake central spot arises a hemispherical protuberance; and at the same time the central cavity loses its semicircular form and becomes divided into four or five irregular lobes, which subsequently become the horizontal supports of the fixed polypary.

(240.) Already the whole expansion is covered with a horny layer:

but this only becomes distinctly recognizable at a more advanced stage of growth.

(241.) The trunk continues to rise vertically upwards, and ultimately produces at its summit a solitary cell, in which a "male" (nutritive) polyp is gradually developed; and then, as growth advances, secondary ramifications are developed, after the pattern peculiar to the species.

(242.) Another important fact in connexion with the history of the Hydrozoa is, that in the compound species there exist male branches as well as female branches upon the same polypary, the latter producing ovigerous vesicles, whilst in the former the ova are replaced by seminal capsules; these almost precisely resemble the "female capsules" (*Beroëform gemmæ*) figured by Lovén, and are, in like manner, surmounted by a circle of tentacula.

(243.) Campanularidæ.—The polypary or common integument of these zoophytes is composed of a semigelatinous horny substance (fig. 47). The older stems assume a dark-brown colour and a consistence resembling that of horn. The young branches, on the contrary, and more particularly the polyp-cells, are thin and perfectly diaphanous. The polypary always exhibits a principal trunk, from which the different branches proceed, every one of the latter being terminated by a bell-shaped cell.

(244.) In the earlier stages of growth the polypary consists of a primary trunk, from which alternating pedicles are given off at regular distances. These pedicles soon become transformed into branches, on which new pedicles in turn make their appearance, as they did on the original stem, exhibiting a dichotomous or trichotomous arrangement.

(245.) At the base of each branch transverse rings are formed (fig. 47, *g*), which are persistent during the life of the polypary. All the branches, as well as the common trunk, increase in their dimensions in accordance with the age of the zoophyte; and, as in vegetables, there is a relation preserved between the thickness of the trunk and the number and extent of the branches.

(246.) Each polyp-bearing cell at the extremities of the branches presents externally a bell-shaped cup, having at its bottom a horny diaphragm, perforated in the centre. It is through this perforation that the body of the polyp is brought into communication with the common fleshy substance of the polypary, and through its intermedium, with the other polyps.

(247.) From the recent observations of Van Beneden* relative to the embryogeny of the Campanularian polyps, it would appear that they frequently undergo, during their development, a series of changes not less wonderful than those exhibited by the other Hydriform races whose history has been carefully traced.

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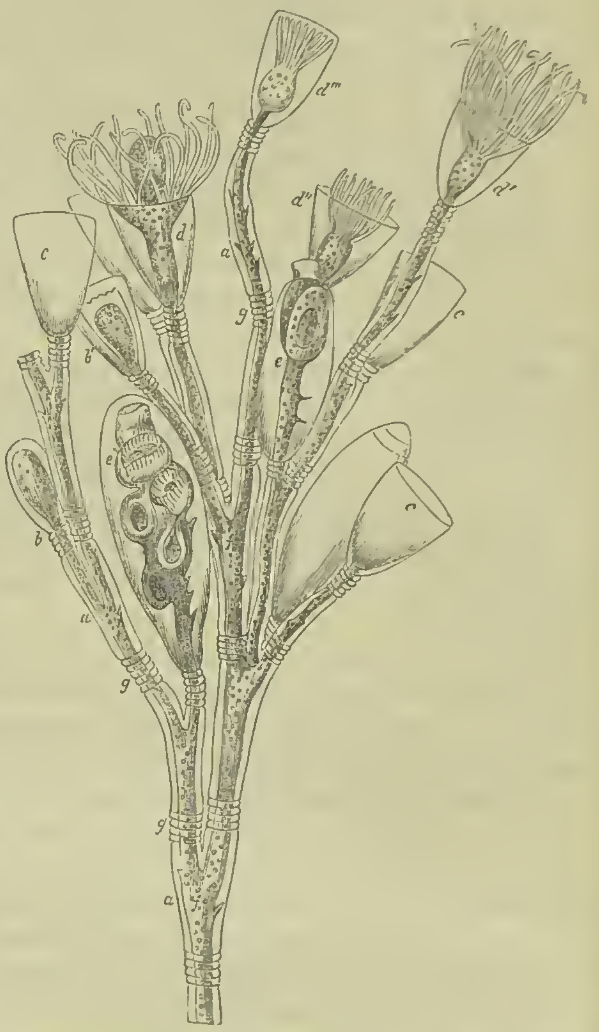
* Nouveaux Mém. de l'Acad. de Bruxelles, vol. xvii. (1843).

(248.) The ovum developed in the ovarian vesicle is, at its first appearance, of a spherical shape, and imbedded in the substance wherewith the deciduous capsule is filled (fig. 47, *e*, *e'*). It is surrounded by a membrane analogous to the calyx of the ovary in buds, which, being torn, discovers the denuded ovum, wherein the vesicles of Purkinje and of Wagner are easily detected; but these very speedily disappear, without any other change in the interior of the egg being discernible.

Fig. 47.



Campanularia gelatinosa. *a a*, tegumentary skeleton, or horny polypary; *b*, *b'*, buds in progress of development into polyps; *c c c*, terminal polyp-cells empty; *d*, *d'*, *d''*, *d'''*, polyps in different stages of growth; *e*, ovarian cell containing an embryo ready to escape; *e'*, another ovarian cell containing several embryos in various states of development; *f*, living substance filling the interior of the horny polypary; *g*, annular constrictions of the horny skeleton. (After Van Beneden.)

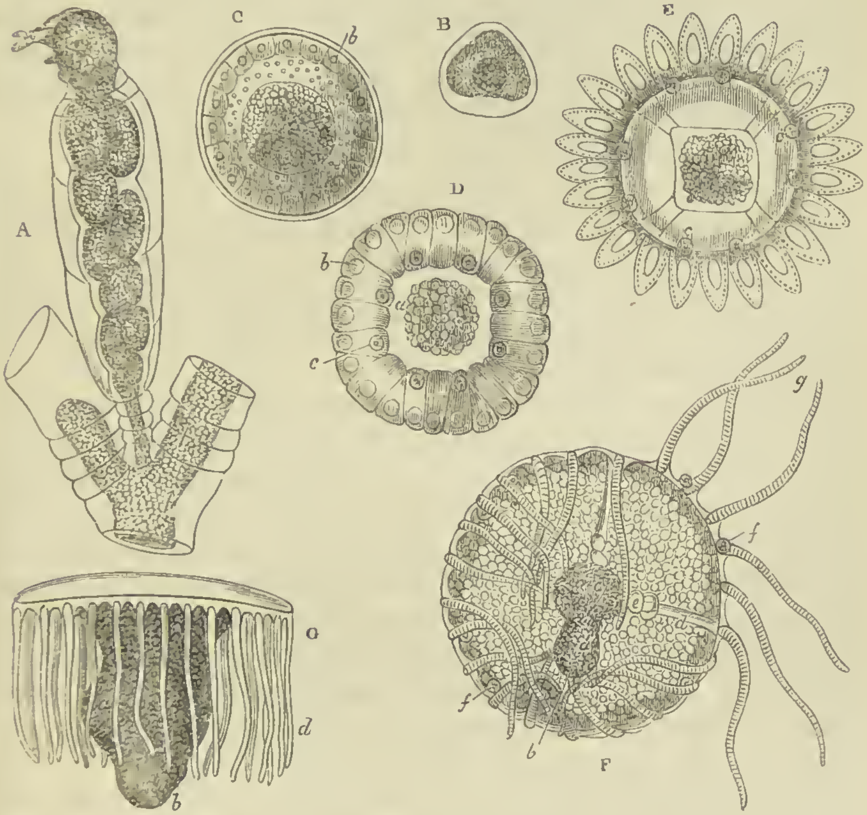
(249.) The next step in the process of development seems to be the conversion of the external vitelline cells into a layer, situated immediately beneath the vitelline membrane, which may be regarded as the representative of the blastoderm.

(250.) The blastoderm now becomes thickened around the vitellus, forming a sort of elevated ring (fig. 48, B), and the positions of the different organs hereafter to be developed become recognizable.

(251.) Certain cells now begin to make their appearance in the interior of the blastoderm, the arrangement of which is particularly remarkable (fig. 48, C & D, *b*); these cells arrange themselves in groups of five around the circumference of the blastoderm, and have the appearance of so many crystals: the form of each group is quadrilateral;

but subsequently, at each angle there is developed another cell, connecting the two groups together, and making the whole number to amount to twenty-four. These twenty-four cells will afterwards become the tentacles of the polyp.

Fig. 48.



Embryology of *Campanularia gelatinosa*. A, an ovarian vesicle from which an embryo is in the act of escaping; others, in a less advanced state, are seen in the interior. B, a detached embryo in a very early stage, showing the vitellus and blastoderm. C, another embryo, more highly magnified: *b*, cells formed around the vitellus. D, the same, more advanced: *a*, cavity enclosing the remains of the vitellus; *b*, elongated cells subsequently developed into tentacula; *c*, other cells, eight in number, which are the rudiments of the organs of the senses. E, the same in a more advanced condition. F, an embryo at the moment of its escape from the ovarian vesicle, magnified: *a*, fleshy pedicle; *b*, mouth; *d*, muscular fasciculus; *e*, nervous ganglion; *ff*, organs of sense; *g*, tentacles. G, the same, as it swims in the water, presenting all the characters of a Medusa.

(252.) Cells of another order now make their appearance (fig. 48, D, *c*), grouped together in pairs, behind the preceding, with similar regularity. These will become organs of sense.

(253.) It is difficult to avoid making the comparison between the above appearances and those of crystallization; the cells, in fact, arrange themselves precisely like crystals, with perfect symmetry, and always in accordance with the number four or its multiple.

(254.) The embryo, at this period of its development, presents the shape of a thick lens-like disk; and shortly, from the centre of its inferior surface, there is developed a tubercle, destined hereafter to become the body of the polyp; it is by this part that it will ultimately become attached.

(255.) The four cells formed between the individual groups above mentioned are, in this stage of the growth of the little being, so compressed that they seem to be quite lost; soon, however, they expand so as to press upon their neighbours, and then the disk appears to be surrounded with a regular series of cellules, twenty-four in number, which, as they become developed, shoot out externally, and soon present themselves under the appearance of so many tubercles (fig. 48, E).

(256.) The eight interior cells (*c c*) take another direction, but their form remains unchanged; and they exhibit, up to the termination of this embryo condition of the animal, a nucleus in the centre of each, which might be regarded either as a crystalline lens or an otolith, according as these organs are judged to be eyes or auditory capsules; for such are the designations applied to them by modern zootomists, as will be explained in the next chapter.

(257.) The marginal tubercles situated around the disk (fig. 48, E) now become sensibly elongated, and the whole embryo presents the appearance of a minute star-fish, the elongate tubercles representing the rays.

(258.) The nuclei in the interior of the marginal (tentacular) tubercles next become elongated, together with their containing cells, rendering the rays hollow in the centre; and soon new cells are discoverable in their interior, the number of which is limited, and probably the same, in all the rays. The appearance of these secondary cells causes a rapid increase in the length of the tentacula, and their remains give rise to numerous septa, producing an appearance somewhat analogous to that of the transverse striæ of muscular fibre.

(259.) The embryo animal, be it observed, is as yet still contained in the ovary of the polyp; but it is already capable of distinct and continual movements, perceptible through the walls of the ovarian vesicle.

(260.) A tubercle (fig. 48, F, *b*) is developed from the centre of the under surface of the disk, which represents the central pedicle met with under various forms among the Medusæ, and which may be called the *proboscidiform appendage.* This organ can contract or extend itself in all directions, constantly changing its form, and resembling in no slight degree the body of a Hydra. At an early period an opening is perceptible at the extremity of this appendage, which evidently represents a mouth, being in direct communication with the vitelline cavity.

(261.) The vitelline or digestive cavity, now that there is a mouth, increases in size in proportion to the growth of the embryo, but still preserves its sac-like shape. It is partially filled up with irregular granules, which become perceptible at a very early period—at first colourless, but gradually becoming of a yellowish tinge. Towards the close of this period of development the granules seem to be heaped together into a mass, from which all the nutritive part appears to have been extracted. This constitutes the *meconium.*

(262.) In some instances, the nutritious fluid that circulates in the interior of the parent polypary may be seen to penetrate as far as the interior of the vitelline cavity of the embryo, which thus seems to derive its nourishment at the expense of the general community; and when it is taken into consideration that the ova are formed in the common fleshy substance lining the walls of the ovarian vesicle, and that the nutritious fluid is diffused throughout its entire mass, it is easy to understand how, after the external membrane surrounding the embryo is ruptured, it is enabled to penetrate, by means of the mouth, into the interior of its stomachal cavity.

(263.) Mention has been made, in the above description (§ 256), of cells which give origin to organs of sensation, and which make their appearance at a very early period. These present the same appearance as the eyes and the ears of the lower mollusca and other inferior animals, and moreover present a similar organization, being composed of two spherical vesicles enclosed one within the other. That the young polyp possesses these organs of relation with the external world is undeniable, although no traces of them remain when the animal has acquired its full development; but what is still more surprising, according to the researches of Van Beneden, coexistent with these instruments of sense, there are perceptible a muscular system and an apparatus of nerves and nervous ganglia which, like the preceding, are only of a temporary character. While the young polyp is still enclosed in its cell, two bands, apparently composed of muscular fibre (fig. 48, F, *d*), make their appearance; these run from one margin of the disk to the opposite edge, crossing each other at right angles, in the centre, so as to present a cruciform arrangement. These bands are quite isolated, and their muscular fibres distinct and transparent. By their action the margins of the disk are approximated, enabling these little animals to imitate the movements so characteristic of the Medusæ.

(264.) Situated upon the course of the bands above described, close to the edge of the vitelline sac, are little rounded bodies (fig. 48, F, *e e*), presenting an irregular and slightly tuberculated surface, considered by Van Beneden to be nervous ganglia. These little bodies are four in number. No filaments of intercommunication or nervous cords have as yet been detected even proceeding to the organs of sensation, but the ganglia seem to be adherent to the muscular bands apparently by the intermedium of nerves.

(265.) It may appear a little rash, says the eminent observer to whom science is so much indebted for these researches, to speak of muscles, nerves, and organs of sensation in the embryo of a polyp, which at a later period presents no traces of the existence of such apparatus; nevertheless the polyp, during its free state, must necessarily require such instruments of sense, to enable it to select a situation adapted to the reception of the new colony to which it gives birth: when once it has made choice of a fit locality, such organs become as useless as they were formerly needful, seeing that all the functions of life are restricted to those of alimentation and reproduction.

(266.) The young Campanulariæ, arrived at this stage of development, abandon the ovarian vesicle of the parent polypary and swim freely about in the surrounding medium, exactly resembling so many young Medusæ (fig. 48, G).

CHAPTER VI.

HYDROZOA (*continued*).

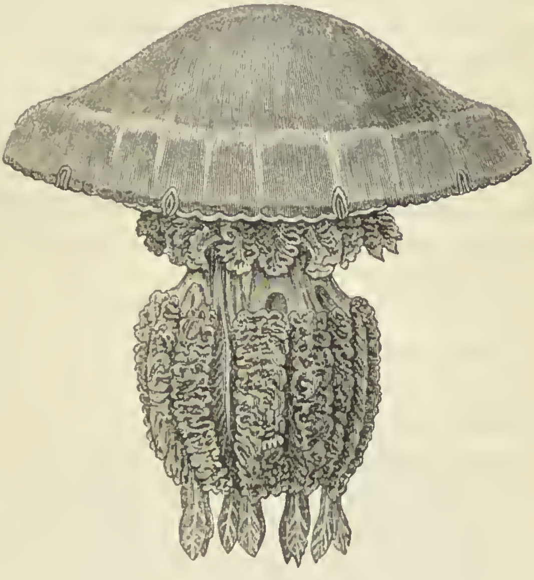
ACALEPHÆ (Cuv.).

(267.) THE ocean, in every climate, swarms with infinite multitudes of animals which, from their minuteness and transparency, are almost as imperceptible to the casual observer as the Infusoria themselves; their existence, indeed, is only indicated by the phosphorescence of some species, which being rendered evident on the slightest agitation, illuminates the entire surface of the sea. All, however, are not equally minute, some growing to a large size; and their forms are familiar to the inhabitants of every beach, upon which, when cast up by the waves, they lie like masses of jelly, melting, as it were, in the sun, incapable of motion, and exhibiting few traces of organization, or indications of that elaborate structure which more careful examination discovers them to possess. Their uncouth appearance has obtained for them various appellations by which they are familiarly known, as Sea-jelly, Sea-blubber, or Jelly-fishes; whilst, from disagreeable sensations produced by handling most of them, they have been called Sea-nettles, Stingers, or Stang-fishes. The faculty of stinging is indeed the most prominent feature in their history: so that their names in almost all languages are derived from this circumstance. They were known to the older naturalists by the title of *Urticæ marinæ*; and the word at the head of this chapter, applied by Cuvier to the entire class, and originally used by Aristotle, is of similar import (ἀκαλήφη, a nettle).

(268.) There are few subjects which come under the observation of the physiologist more calculated to excite his astonishment than the history of these creatures. If he considers, in the first place, the composition of their bodies, what does he find? An animated mass of sea-water; for such, in an almost literal sense, they are. Let him take an Acaleph, of any size, and lay it in a dry place: it will be found gradually to drain away, leaving nothing behind but a small quantity of transparent cellular matter almost as delicate as a cobweb, which apparently formed all the solid framework of the body, and which, in an animal weighing five or six pounds, will scarcely amount to as many grains; and even if the water which has escaped from this cellulosity be collected and examined, it will be found to differ in no sensible degree from the element in which the creature lived. The conclusion therefore at which he naturally arrives is, that, in the Acalephæ, the sea-water collected and deposited in the delicate cells of an almost imperceptible film becomes, in some inscrutable manner, instrumental to the exercise of tho extraordinary functions with which these creatures are endowed.

(269.) The Acalephæ have been divided by zoologists into groups distinguished by the nature of their means of progression: in describing, therefore, the organs of locomotion, with which we commence their history, the reader will be made acquainted with the principal modifications of outward form exhibited by various races of these interesting beings.

Fig. 49.



Rhizostoma Cuvieri.

(270.) Pulmonigrada.—The most ordinary examples of the Acalephæ found in our climate, when examined in their native element, are seen to be composed of a large mushroom-shaped gelatinous disk, from the inferior surface of which various processes are pendent, some serving as tentacula, others for the prehension of food. In *Rhizostoma* (fig. 49) the central pedicle resembles in structure and function the root of a plant, being destined to absorb nourishment from the water in which the creature lives. The body of one of these Medusæ is specifically heavier than the water of the ocean, and would consequently sink but for some effort on the part of the animal. The agent employed to sustain it at the surface, and in some measure to row it from place to place, is the umbrella-shaped expansion or disk, which is seen continually to perform movements of contraction and dilatation, repeated, at regular intervals, about fifteen times in a minute, having some resemblance to the motions of the lungs in respiration, whence the name of the order (*pulmo*, the lung; *gradior*, I advance). By these constant movements of the disk, the Medusa can strike the water with sufficient force to ensure its progression in a certain direction when swimming in smooth water; but of course such efforts are utterly inefficient in stemming the course of the waves, at the mercy of which these animals float. The tentacular appendages, situated around the margin of the disk in such species as are provided with these organs, are likewise capable of contractile efforts, and may in some slight degree assist as agents of impulsion, although they are destined to the exercise of other functions. The locomotive disk, when cut into, seems perfectly homogeneous in its texture, nor is any fibrous appearance easily recognizable, to which its movements could be attributed; nevertheless in the larger species its inferior surface appears corrugated, as it were, into minute radiating plicæ, which seem to contract more energetically than the other portions, and resemble a rudimentary development of muscular fibre.

(271.) In the Acalephæ, indeed, the substance of the body is generally entirely soft and gelatinous, emulating, in the delicacy of its texture and perfect translucency, the structure of the vitreous humour of the eye, its entire organization apparently consisting of a transparent aqueous fluid contained in innumerable polyhedral hyaline cells. In some species, however, certain parts of the animal are of semicartilaginous tissue; and in a few instances cartilaginous or calcareous lamellæ are found imbedded in their substance, which may be compared to a rudimentary polypary or internal skeleton.

(272.) Interesting as these creatures may justly be considered when we contemplate the singular beauty of their external configuration and the wonderful design conspicuous in their locomotive organs, a more intimate acquaintance with their habits and economy will be found to disclose many facts not less curious in themselves than important in a physiological point of view. In the higher animals, we are accustomed to find the nutritive apparatus composed of several distinct systems—one set of organs being destined to the prehension of food, another to digestion, a third to the absorption of the nutritious parts of the aliment, a fourth provided for its distribution to every part of the body, and a fifth destined to ensure a constant exposure of the circulating fluid to atmospherical influence; these vital operations are carried on in vessels specially appropriated to each; but in the class of animals of which we are now speaking, we find but a single ramified cavity appropriated to the performance of all these functions, and exhibiting, in the greatest possible simplicity, a rough outline, as it were, of systems afterwards to be more fully developed.

(273.) In the *Pulmonigrade Acalephæ* we have the best illustration of this arrangement: in these, the stomach or digestive cavity is excavated in the centre of the disk, and is supplied with food by a mechanism that differs in different species. In *Rhizostoma* (fig. 49), which receives its name from the nature of the communication between the stomach and the exterior of the body*, the organ destined to take in nourishment consists of a thick pedicle, composed of eight foliated divisions, which

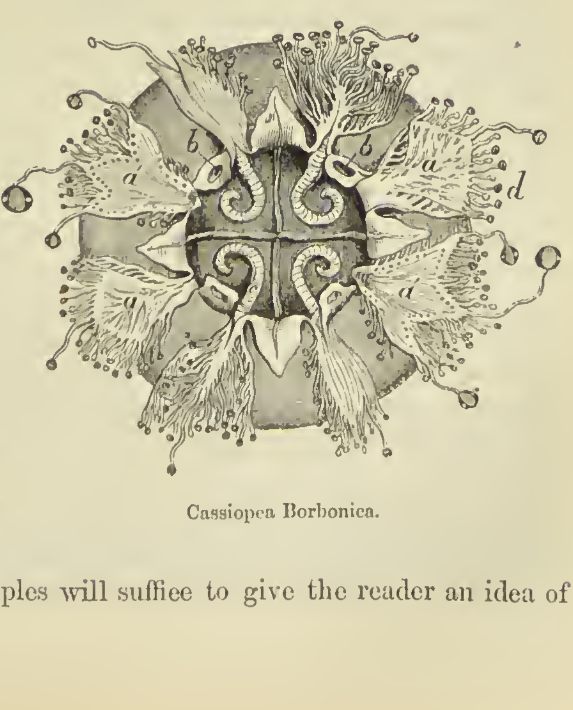
* *ῥίζα*, a root; *στόμα*, a mouth.

hang from the centre of the disk. Each of these appendages is found to contain ramifying canals, opening at one extremity by numerous minute apertures upon the external surface, whilst at the opposite they are collected into four large trunks communicating with the stomach; as the Rhizostoma, therefore, floats upon the waves, its pendent and root-like pedicle absorbs, by the numerous oscules upon its exterior, such food as may be adapted to its nutrition, finding most probably an ample provision in the microscopic creatures which so abundantly people the waters of the ocean. The materials so absorbed are conveyed through the canals in the interior of the arms into the stomachal cavity, where their solution is effected.

(274.) But it is not upon this humble prey that some of the Medusæ feed; many are enabled, in spite of their apparent helplessness, to seize and devour animals that might seem to be far too strong and active to fall victims to such assailants: crustacea, worms, mollusca, and even small fishes are not unfrequently destroyed by them. Incredible as this may seem when we reflect upon the structure of these feeble beings, observation proves that they are fully competent to such enterprises. The long tentacula or filaments with which some are provided, form fishing-lines scarcely less formidable in arresting and entangling prey than those of the Hydra; and, in all probability, the stinging secretion which exudes from the bodies of many species speedily paralyses and kills the animals which fall in their way. The mouth of these Acalephæ is a simple aperture leading into the gastric cavity, and sometimes surrounded with tentacula, that probably assist in introducing the food into the stomach.

(275.) In *Cassiopea Borbonica*, the principal agents in procuring nourishment are numerous retractile suckers (fig. 50, *a*), terminating in small violet-coloured disks, which are dispersed over the fleshy appendages to the under surface of the body; the stem of each of these suckers is tubular, and conveys into the stomach nutritive materials absorbed from animal substances to which they are attached during the process of imbibing food.

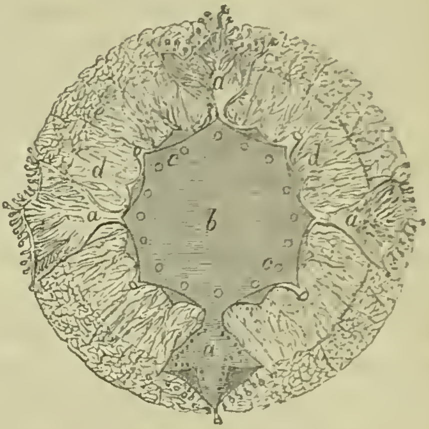
Fig. 50.



Cassiopea Borbonica.

(276.) The above examples will suffice to give the reader an idea of the most ordinary provisions for obtaining nourishment met with in the Pulmonigrada; we will therefore return to consider the structure of the stomach itself, and of the canals that issue from it and convey the digested nutriment through the system. In *Cassiopea Borbonica*, which will serve to exemplify the general arrangement of these parts in the whole Order, the stomach (fig. 51, *b*) is a large cavity placed in the centre of the inferior surface of the disk, and is apparently divided into four compartments by a delicate cruciform membrane arising from its inner walls. Into this receptacle all the materials collected by the absorbing suckers are conveyed through eight large canals, and by the process of digestion become reduced to a yellowish semi-fluid pulpy matter constituting the pabulum destined to nourish the whole body. From the central stomach sixteen large vessels arise (fig. 51, *c*), which radiate towards the circumference of the disk, dividing and subdividing into numerous small branches that anastomose freely with each other, and ultimately form a perfect plexus of vessels as they reach the margin of the mushroom-shaped body of the creature. The radiating vessels are moreover made to communicate together by means of a circular canal (fig. 51, *e*) which runs round the entire animal, so that every provision is made for an equable diffusion of the nutritive fluid derived from the stomach through the entire system. Now, if we come physiologically to investigate the nature of this simple apparatus of converging and diverging canals, we cannot but perceive that it unites in itself the functions of the digestive, the circulatory, and the respiratory systems of higher animals: the radiating canals, conveying the nutritive juices from the stomach through the body, correspond in office with the arteries of more perfectly organized classes; and the minute vascular ramifications in which these terminate, situated near the thin margins of the locomotive disk, as obviously perform the part of respiratory organs, inasmuch as the fluids permeating them are continually exposed to the influence of the air contained in the surrounding water, the constant renewal of which is accomplished by the perpetual contractions of the disk itself.

Fig. 51.



Cassiopea Borbonica.

(277.) The umbrella-like disk of *Cyanea aurita*, whose anatomy has been most carefully studied by Ehrenberg, is composed of a highly organized gelatinous substance invested by three membranous integuments, the structure of which is by no means so simple as has been generally imagined. The exterior of these tegumentary membranes, covering the convex surface of the disk, consists of a dense tissue made up of hexagonal cells containing a soft whitish substance mixed up with little granules, and presents upon its outer surface innumerable little suckers or agglomerations of granular bodies, which are visible to the naked eye.

(278.) The concave or ventral surface of the disk is furnished with a double investment, consisting of an outer and inner layer, the external of which resembles in its structure the dorsal membrane described above, and constitutes a sort of epidermic covering. The inner layer, which in its intimate texture likewise consists of hexagonal cells, encloses nothing but a number of isolated granules, clear and translucent as water. The interspace between this inner layer and the dorsal integument is considerably greater than that which separates it from the ventral surface; both these spaces, however, are filled up with a clear gelatinous mass, wherein are distinguishable numerous isolated granular bodies, of a rounded shape and of unequal size, that seem to be all connected with each other by fibres or extremely delicate vessels, and not supported by expansions of cellular membrane. The rest of the gelatinous mass is too transparent to allow any organization to be detected; this, however, is in small proportion, and encloses the large vessels belonging to the nutritive apparatus, immediately to be described.

(279.) The opening of the mouth is situated in the centre of the lower surface of the disk, between the four arms suspended from that portion of the body. The mouth itself consists of a short quadrangular tube, from the angles of which the arms are dependent. Each arm is composed of a thick central cartilage, whereunto are attached two membranous laminæ, variously plaited and puckered throughout their entire length, and moreover at certain seasons gathered into little pouches or pockets, to be hereafter mentioned in connexion with the generative apparatus.

(280.) Superiorly the oral aperture terminates in four short tubes arising from its four angles; and these, diverging, mount upwards, supported by a cartilaginous prolongation derived from the central supports of the arms. These four tubes evidently represent the œsophagus and lead into four ample stomachs of a subglobular shape, which are smooth internally and lined by a special membrane, wherein may be seen numerous little granular bodies, but no vessels.

(281.) From the above stomachal cavities proceed several large canals that diverge towards the circumference of the disk, and constitute a part of the digestive apparatus. One of these vessels arises immediately from the dilated portion of each œsophageal tube; and these, dividing and subdividing dichotomously, ramify towards the margin of the disk. From each of the four stomachs three other large canals take their origin, and run in the same direction; of these, the two lateral ones are simple and unbranched, but that in the centre ramified dichotomously. These sixteen large vascular trunks, together with all their numerous ramifications, sometimes anastomotically united, ultimately terminate in a wide circular vessel that surrounds the margin of the disk. The nutrient canals are situated beneath the inner membrane, described above, whereby they are partially enclosed and supported.

(282.) Before closing our description of the alimentary system of the Pulmonigrade Acalephæ, we must mention some accessory organs, of recent discovery, which are in connexion with it. Eschscholtz* describes a series of elongated granular bodies, placed in little depressions around the margin of the disk, which seem to be of a glandular nature, and apparently communicate by means of minute tubes with the nutrient canals: these he regards as the rudiments of a biliary system. Other observers assign a similar office to a cluster of blind sacculi or cæca, which are connected in some species with the commencement of the radiating tubes; it is, however, scarcely necessary to observe that such surmises relative to the function of minute parts are but little satisfactory.

(283.) Prior to the publication of Ehrenberg's important researches relative to the anatomy of the *Cyanea aurita*†, it was generally believed that in the Pulmonigrade Medusæ the alimentary canals were unprovided with any excrementitious orifices; these, however, were discovered by the illustrious Prussian observer, occupying the situations indicated by eight dark-brown-coloured spots situated at equal distances around the margin of the disk, and which had previously been suspected to be the analogues of a biliary organ. By keeping the living Medusæ for some time in sea-water deeply coloured with indigo, and thus causing all the ramifications of the alimentary apparatus to become filled with the coloured fluid, while the rest of the body remained transparent and colourless, it appeared that, opposite each of the above-mentioned spots, the circular marginal canal into which the nutritive tubes, radiating from the stomach, empty themselves becomes dilated into a sort of cloacal cavity, in which the débris of digested materials, such as the shells of minute Conchifera, Rotifera, Bacillaria, &c., were easily distinguishable; from each of these cloacal dilatations, canals can readily be traced communicating with the exterior; and on irritating the living animal, it is easy to witness the discharge of excrementitious matter through the eight marginal orifices of the disk.

(284.) A distinct movement is frequently perceptible in the interior of the ramifying alimentary tubes, which has been mistaken for a circulation, but which is merely the effect of ciliary action, or of peristaltic movement in the walls of the intestine.

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* System der Acalephen. Berlin, 1822.—Annales des Sciences Naturelles, vol. xxviii. p. 251.

† Abhandl. der Königl. Akad. der Wissenschaften zu Berlin, 1835.

(285.) Up to the period when Ehrenberg made the important researches we are laying before the reader, relative to the anatomy of these creatures, it was impossible to account for the capability of locomotion which the Pulmonigrade Acalephæ evidently possess, but which his researches serve to render perfectly intelligible. The canals formed by the ramifications of the alimentary apparatus he observed to be all bordered by two delicate lines of a pale red colour, which, under the microscope, are evidently of a muscular character; by the contractions of these, therefore, the most important movements of the animal are accomplished. Besides the above, however, other muscles are discernible. In *Cyanea* the disk is surrounded with a fringe of tentacula, each of which exhibits at its base a muscular structure; consequently the possession of muscular fibre is evidently established as a part of the economy of these animals.

(286.) It is very probable that the older writers, who speak of a circulation of blood in the Medusæ, only alluded to the movements observable in the contents of the intestinal ramifications; it appears, however, from Ehrenberg's observations, that in the Medusæ there exist distinct globules, which are of a uniform round shape, enclosed in distinct vessels, wherein a kind of circulation is carried on: these globules he describes as being colourless, spherical, simple, and varying from $\frac{1}{288}$th to $\frac{1}{300}$th of a line in diameter.

(287.) Although the Medusæ have always been admitted to possess considerable sensibility, no traces of a nervous system had been detected in their soft and delicate tissues until Ehrenberg pointed out a structure apparently of a nervous character. On carefully examining the eight brown-coloured spots which are disposed at equal distances around the margin of the disk (fig. 48, F, *f*), he found them to present a very elaborate and remarkable organization. Each of these coloured spots is seen, when accurately observed, to be composed of a little button-like appendage, of an oval or cylindrical shape, attached to the extremity of a slender pedicle, which in turn takes its origin from a kind of vesicle, wherein may be perceived, by means of the microscope, a glandular-looking substance. On the dorsal aspect of each of the pedunculated brown-coloured appendages is situated a distinctly marked round spot of a bright red colour, supposed by Ehrenberg to be an ocular organ, while he considers the glandular-looking substance above mentioned to constitute a nervous ganglion. In addition to this arrangement, he considers that there exist, running all along the margin of the disk, in each of the interspaces between the marginal tentacles, a series of ganglia of a similar character, giving off nerves to the tentacula, whilst other ganglia are to be detected in the tentacular appendages situated in the vicinity of the œsophagus, as well as in the oviferous cavities. In short, he states the general distribution of the nervous matter in the Medusiform Acalephæ to be as follows:—Four groups of nervous ganglia are situated around the œsophagus in the oviferous cavities close to the ovaria, which are in communication with as many groups of tentacula. Upon the outer border of the disk, close to the base of the marginal tentacles, is another series of nervous nodules, interrupted at regular intervals by the eight brown-coloured corpuscles. Lastly, there exists a series of isolated ganglionic masses, eight in number, situated at the bases of the supposed ocular organs, to which they give off nervous filaments.

(288.) The so-called ocular organs, named by Ehrenberg unhesitatingly "pedunculated eyes," present a very remarkable structure. Each "pedunculated eye" is directed towards the dorsal aspect of the disk, and has, situated beneath its lower surface, a minute sacculus of a yellowish colour, but variable in its shape, wherein is contained a number of solid crystals, clear as water, and which the action of acids proves to be composed of carbonate of lime.

(289.) Not only *eyes*, however, but *ears* also are conceded by modern naturalists to these favoured occupants of the ocean.

(290.) At the base of the marginal tentacula, or cirri, says Professor Forbes*, there are present, in a great many of these animals, coloured spots or bulbs; and in some species these points are so strongly coloured, that, from this circumstance and their magnitude, they indicate the course of the animal when in motion, appearing like a circle of gems in the water. When these bulbs are examined with the microscope, they are found to contain a small cavity, quite distinct from any coloured matter that may be present; the former is regarded by modern naturalists as an *otolithic vesicle*, the latter as an ocellus, or eye-spot.

(291.) The otolithic vesicle, which, from analogy and its peculiar structure, is considered as an organ of hearing, is a small spherical sac, developed in the midst of the granular substance of the bulb, and containing more or fewer minute vibrating bodies. Will has described the otolithic vessel and its contents, as they are found in *Geryonia*, as follows:—"The auditory vesicles are seated in the course of the marginal circular vessel, in very uncertain number; usually, however, one at each side of the larger marginal cirri. They are round, measuring $\frac{1}{40}$th of a line in diameter, and consist of a tolerably thick membrane; they contain from one to nine, and even more, round globules. If there is only one, it is situated exactly in the centre of the vesicle; but if there are several, they are found lying together, either in two groups, or joined to each other. I have never observed them move. Muriatic acid dissolves them, and causes the vesicle to burst." The existence of similarly-constructed organs has been recognized in many other species by various observers.

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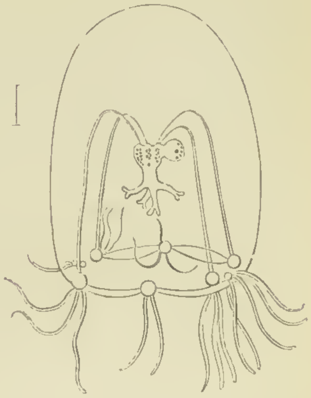
* Monograph on the British Naked-eyed Medusæ.

Fig. 52.



Lizzia octopunctata.

(292.) It was discovered by Sars*, that certain forms of naked-eyed Medusæ multiply their species by means of *gemmation*, the buds being produced either from the walls of the peduncle or stomachal proboscis, or from the surface of the ovaries. In both cases the new individuals were not different from, but similar to, their parents; and in one instance, provision seemed to be already made in the newly-formed offshoots for continuing to propagate by the same mode other individuals similar to themselves. From a certain part of the body roundish knobs grow forth, which gradually assume the shape of a bell, by opening themselves at the free end, and soon present the form of young Acalephs, being merely attached to the mother by means of a short peduncle, derived from the back of the disk. These develope in themselves all essential organs whilst still attached to the mother, like the buds of a plant, until at length, after a certain time, they separate from the parent and swim about as independent individuals.

(293.) Professor Forbes, in his admirable monograph upon the British Naked-eyed Medusæ, not only confirms the above important observation of the Norwegian naturalist, but describes four different modes of gemmiparous reproduction as occurring in that group of the Acalephæ. 1st, gemmation from the ovaries, as noticed by Sars in *Thaumantias multicirrata*; 2nd, a mode of gemmation from the pedunculated stomach, which he calls subsymmetrical, because in this case four gemmæ are symmetrically arranged round the peduncle, one of which is constantly in a more advanced condition of development than the other three; 3rd, gemmation irregularly from the walls of a tubular proboscis—in which there is no order of development with respect to position, individuals springing indifferently from various parts of the peduncle (fig. 52); and a fourth mode, which is very remarkable, in a new British species named *Sarsia prolifera*, in which the buds are produced at the bases or tubercles of the four marginal tentacles, and hang from them in bunches like grapes. The degree of development is not equal in all four bunches, and in each case buds are seen in very various stages of advancement, from embryo wart-like sproutings to miniature Medusæ, simulating, in their essential characters, the parent animal.

(294.) We have already seen, at the close of the last chapter, that the progeny of the Hydriform polyps, during one phasis of their development, were strictly medusoid in their form and organization; and in like manner it is now incontrovertibly established that the Acalephæ are, at a certain stage of their growth, to all intents and purposes Hydriform polyps, as will be immediately evident.

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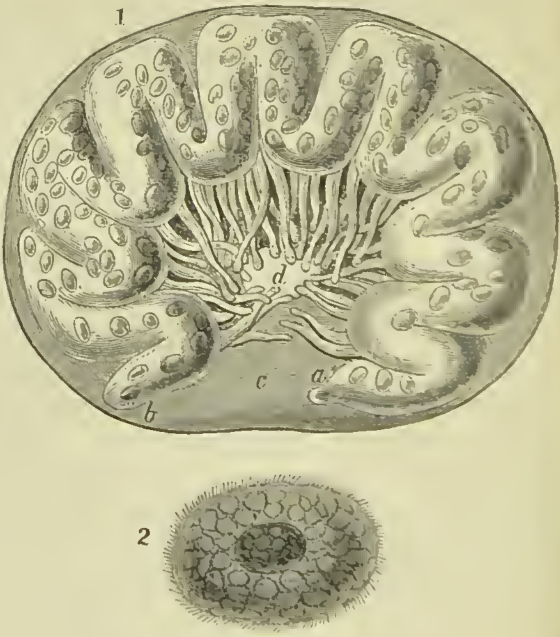
* Fauna Norvegica.

(295.) The Acalephs are now universally admitted to be bisexual; and the generative apparatus in both sexes is invariably found to be more or less intimately in relation with the alimentary canal: that is to say, as in the case of the polyps, the reproductive organs are appendages derived from the internal or nutritive system of the body. In both the males and females of the great majority of genera, the testes of the former and the ovaria of the latter are similarly disposed, and present externally precisely the same structure, consisting of duplicatures of a delicate membrane, between which, in the case of the female, ova are developed in great numbers, generally of a rich orange or purple colour, so as to be conspicuously visible. In the male Acaleph, instead of ova, the generative membrane secretes a vivifying fluid, rich in spermatozoa, and consequently easily recognizable under the microscope.

(296.) In *Cyanea aurita* the generative apparatus of the female consists of four membranous ovaria, easily recognizable on account of their bright colour, which is usually violet, or deep yellow. Their form is generally semicircular (fig. 53), and they are lodged in as many distinct cavities, situated in the immediate vicinity of the central stomachs. Each of these cavities communicates freely with the external element by means of a large round or oval orifice, furnished internally with tentacula having suckers at their extremities (fig. 53, *d*.) The four semicircular ovaries are each composed of a simple contorted tube (fig. 53, *a*, *b*): when full of eggs, its colour is a beautiful violet; but when empty, or when the ova are only partially developed, a yellowish brown.

Fig. 53.



1. Ovarium of *Cyanea aurita*.
2. Ciliated embryo after its escape.

(297.) The ova are not retained in the ovaria during the whole time of their development, neither do they remain in the ovigerous cavity, but escape from the orifice of the latter into the surrounding water, from whence they are again taken up by the tentacula and by the two laminæ of the arms, and become lodged in little pouches formed by the laminated margin, in which they undergo further metamorphosis and development. These ovigerous pouches are only met with at certain seasons, disappearing when their functions are accomplished.

(298.) The eggs are of a rounded form and covered with a smooth, thin, membranous envelope whilst they remain in the ovary; internally they are filled with a finely-granular mass of a violet hue.

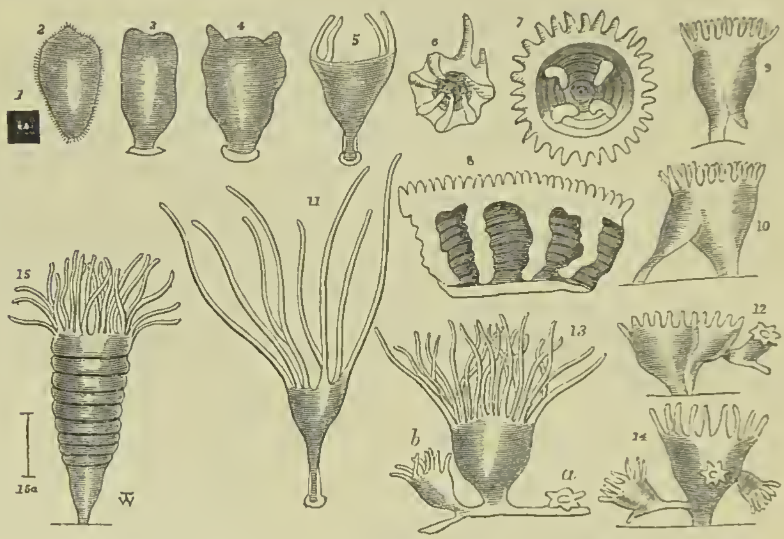
(299.) The ova contained in the arm-sacculi are destitute of any shell, and present themselves under three distinct forms, which are very remarkable. Some resemble blackberries, and are of a pale violet hue; others have the shape of minute thick disks, likewise violet, resembling little Medusæ deprived of arms and without any nutrient canals; lastly, others are met with (and these latter are the most numerous) which have a cylindrical shape, truncated at both ends, and of a brownish-yellow colour. The two last-mentioned forms are densely covered with cilia, and swim about with facility; the largest among them measure about $\frac{1}{8}$th of a line in diameter.

(300.) Subsequently the ciliated embryos, escaping from their confinement, detach themselves from the cradles wherein they have been nursed up to this period, and swim freely about in the surrounding water until ripe for a further change in their economy; they then settle down upon some foreign object, such as a piece of sea-weed, to which they attach themselves by one extremity (fig. 54, 3), assuming the appearance of a contracted Hydra, but, as yet, unprovided either with mouth or tentacula; gradually, however, an oral aperture and stomachal cavity, surrounded by tentacular organs, become apparent; and as these progressively increase in number (fig. 54, 4, 5, 6, 11), the little creature assumes completely the polyp form, and, what is still more wonderful, acquires in this early and, as it might be called, larva-condition of its existence the power of multiplying itself under the same shape, apparently *ad infinitum.*

(301.) This kind of reproduction is effected by the development of *stolons, gemmæ,* and *bulblets* from any portion of the surface of the polypoid animal, which in turn give origin to similar offsets (fig. 54, 12, 13, 14), precisely resembling, when mature, the original polypoid body.

(302.) The next phasis in the development of these Acalephs is one of the most remarkable circumstances connected with their history, and, were it not for the accumulated testimony of numerous observers, might appear almost incredible. The polyp, much in the condition represented at fig. 54, 11, is immovably fixed by its basis to the surface of a Fucus, or some similar support; in length it is about $\frac{1}{8}$th, and in diameter $\frac{1}{16}$th of an inch; its surface is smooth, and its texture altogether gelatinous; its tentacles are movable in all directions and exceedingly irritable, and its whole structure and appearance, in short, that of a gelatinous polyp or Hydra. But a great change is now in preparation: the body of the Hydriform polyp gradually increases in size; and transverse folds begin to make their appearance at equal distances, one below the other, partitioning off its body into numerous rings or segments (fig. 54, 15).

Fig. 54.

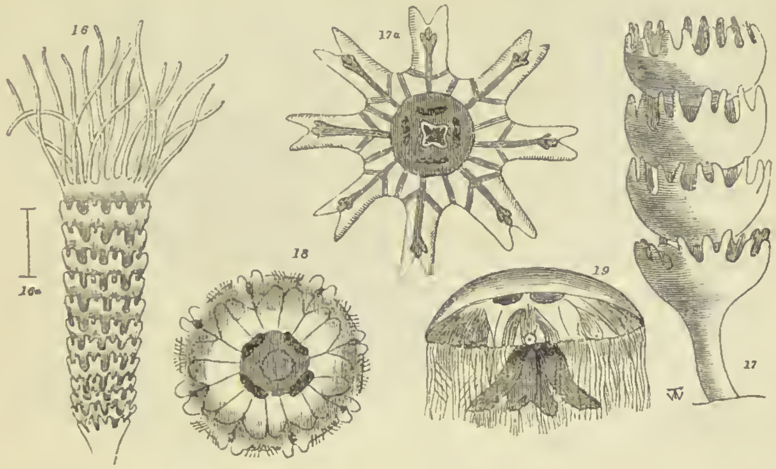


Development of *Cyanea capillata* (after Sars, 'Annales des Sciences Naturelles' for 1841, plates 15 B, 16, & 17, pp. 19, 50). 1. Young Acalephs newly hatched (natural size). 2. One magnified, showing infusorial condition of development. 3, 4, 5, 6. The same animal now become attached by a pedicle, and gradually assuming the polypoid form. 7. A still more advanced condition, showing the mouth surrounded by numerous retracted tentacula: the mouth is dilated, exhibiting four longitudinal eminences, situated in the stomachal cavity. 8. The same individual cut open longitudinally, and spread out so as to show the longitudinal eminences in the interior: the transverse lines are caused by the contraction of the body. 9, 10. Two polypoid Acalephs, with *stolons* developed from the upper part of the body: in fig. 10 the stolon has become attached to the supporting surface. 11. Fully-developed polyp. 12. Another individual giving off a stolon, from which proceeds a second that in like manner gives off a third offset. 13. Stolons growing off from the base of the polypoid Medusa, which, creeping along the surface of the substance to which it is attached, give origin to new polyps, *a*, *b*. 14. Three young gemmæ sprouting from the body of a polypoid Acaleph. 15. A polypoid larva magnified (the natural size is shown at 15 *a*), having its body divided by numerous transverse wrinkles.

(303.) In the course of a short time the segments thus formed become surrounded with marginal rays dichotomously divided at their extremities. These rays or arms are free, having their apices directed upwards, and disposed with such regularity that the once polypoid body seems to be furnished with eight longitudinal ribs (fig. 55, 16).

(304.) We now arrive at the fourth period of the process, when the different segments into which the original polyp has become divided separate from each other, so as to form so many distinct disks (*Planula*, Dalyell), each of which on its separation becomes a complete animal. This separation commences at the upper extremity of the series of newly-formed beings, and is repeated, segment after segment, towards the base, each segment as it becomes detached presenting the form, characters, and attributes of a free Acaleph, and in this condition assuming an independent existence, under the appearance represented in fig. 55, 17, *a*.

Fig. 55.



Transformation from the polypoid form to the third, or Acaleph, condition (after Sars). 16. The polypoid larva (16*a*, natural size) in a more advanced state, now divided into segments piled upon each other, each of which is a young Medusa, having its disk surrounded with radiating processes bifurcated at their extremities. These segments becoming detached one by one from the summit of the pile successively, assume the medusiform condition. 17. Another example, in progress of division, in which only four segments remain undetached, and of these the three uppermost are at the point of separation. 17 *a*. A segment of the preceding detached, now become a free Acaleph: it is represented as seen from below, and already exhibits in its centre the square oral orifice, round which are perceptible rudimentary tentacula, together with the radiating nutritive canals, &c. 18. The same, in a still more advanced stage, exhibiting the rudiments of marginal tentacula. 19. The same, arrived at its perfect form, furnished with its four buccal arms, now completely divided and pendent, and fully provided with the marginal tentacles of the adult.

(305.) The now free Acaleph, the disk of which is not as yet much more than $\frac{1}{8}$th of an inch in diameter, exhibits, when magnified, the characteristic organization of a true Medusa,—the oral orifice (fig. 56, *a*), the positions of the ovaria *b*, the radiating nutritive canals, *c*, the circular marginal vessels, *d*, the oculiform points, *e*, the anal apertures, *f*, and the rudimentary tentacula surrounding the disk, *g g*, being all easily recognizable. The Medusa being thus far complete, its further advance is rapid, the rays become gradually shorter in proportion to the disk, the marginal tentacles are more and more developed, and at length the young Acaleph, complete in all its parts (fig. 55, 19), will in time, by the production of multitudinous ova, give birth to another generation, destined, during their development, to exhibit a parallel series of changes.

(306.) In some of the Medusæ which are destitute of a central pedicle, such as *Cuvieria carisochroma* (fig. 57), the arrangement, both of the alimentary and generative apparatus, is considerably modified. In *Æquorea violacea*, examined by Milne-Edwards*, the gastric cavity, which is very large, occupies nearly a third of the whole diameter of the disk; the oral aperture, instead of being pedunculated, is simply surrounded with a membranous border, hanging loosely down when in a state of repose, and so short as to be quite inadequate to close the opening of the mouth. Superiorly this membranous border is attached to a ring, slightly more callous in its structure than the rest of the body, immediately above which is a circle of tolerably wide orifices placed very close to each other, all of which lead into radiating canals that diverge towards the circumference of the disk. These canals, seventy-four in number, becoming narrower as they recede from the stomachal cavity, run in straight lines to terminate in a circular vessel that surrounds the disk near its margin, from which little canals are given off, apparently analogous to the emunctory vessels above described as existing in *Medusa aurita*.

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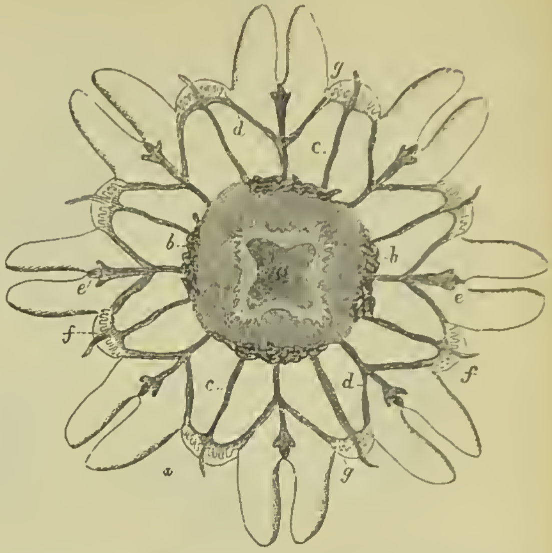
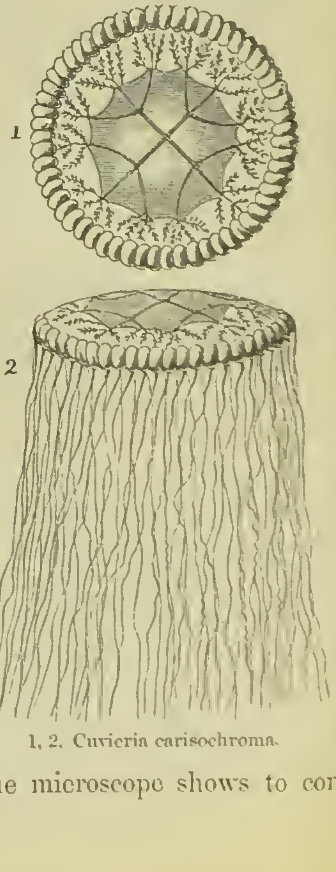
* Ann. des Sci. Nat. for 1841.

Fig. 56.



Young Medusa (after Sars). *a*, the mouth, surrounded with the as yet undeveloped buccal arms; *b b b b*, ovaria, or testes; *c*, radiating nutritive canals; *d*, marginal circle of nutrient vessels; *e*, oculiform organs; *f f f*, anal apertures situated on the margin of the disk.

Fig. 57.



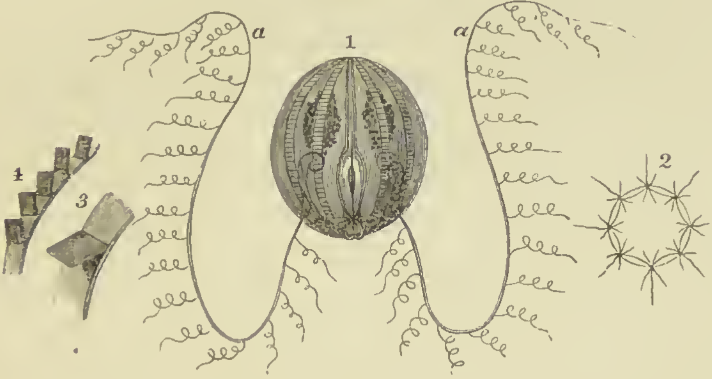
1, 2. Cuvieria carisochroma.

(307.) The generative system in *Æquorea* is in relation with this arrangement of the nutritive canals. Arising from the under surface of the disk there are numerous membranous lamellæ disposed in a radiating manner around the gastric cavity. These lamellæ seem to be suspended from beneath each radiating canal; consequently they are seventy-four in number; and being much folded upon themselves, each has the appearance of being formed of a double membrane. In their interior they exhibit numerous striæ of a violet hue, which the microscope shows to constitute the generative apparatus. In some individuals these folded membranes enclose the ova, and in others contain a fluid filled with spermatozoa; so that they evidently represent the ovaria and testes of these Acalephs.

(308.) Ciliograda.—In the *Ciliograde Acalephæ* (Ctenophora), the organs of motion consist of narrow bands of vibratile cilia, variously disposed upon the surface of the animal.

(309.) In the globular forms of the *Beroës* (fig. 58), these cilia are arranged in eight longitudinal rows, and appear to be attached to subjacent arches of a firmer consistence than the rest of the body. They are generally quite naked, but in *Pandora* are lodged between folds of the skin, which afterwards close over and completely conceal them; their motion is extremely rapid, and sometimes only recognizable by the currents they produce, or by the iridescent hues that play along the arches.

Fig. 58.



1. Cydippe pileus: *a*, tentacula unfolded. 2. Supposed nervous system. 3, 4. Isolated cilia.

(310.) The arrangement of the locomotive apparatus appended to the eight longitudinal costal bands is extremely beautiful. The series of vibratile fringes is attached to a row of minute transverse ridges, disposed almost like the steps of a ladder, and, moreover, in their essential structure they differ very materially from vibratile cilia of the ordinary character. In shape they are not filiform, but resemble membranous laminæ deeply fringed around their free margin, having the shape of so many little semi-oval palletts. The movements of these flabelliform appendages are very rapid, and are seldom interrupted while the animal is in vigorous health; the slightest contact, however, is sufficient to stop them. The different laminæ, moreover, belonging to the same row are quite independent of each other; neither does interference with one produce the slightest effect upon the action of the rest. The animal, nevertheless, seems to possess the power of arresting or controlling their motions at pleasure. It is likewise remarkable that the vibratory movement is kept up for a very long time in fragments separated from the rest of the body, without at all changing its character;

but it may be observed that, in portions thus detached, the sensibility appears to be destroyed before the contractile power, inasmuch as, after a certain time, the vibration is kept up unintermittingly in spite of such contact as would previously have caused a suspension of vibratory action.

(311.) The cilia, which are placed on the longitudinal ridges, are linear-lanceolate in form, flat, and not hollow. They are not webbed together, and have no communication with the vessels that run beneath the ciliary ridges. Each row of cilia is mounted on a transverse base, of a more solid texture and less transparent than the rest of the body. The substance of this base consists of globules irregularly imbedded in a homogeneous substance. When one of the cilia of a *Cydippe* is cut off, it has of itself no power of motion; but if the smallest portion of the substance of its base remains attached, it moves with great vivacity. Hence it is concluded that the ciliary motion is effected by undulatory movements of this peculiar tissue.

(312.) In the Beroëform Acalephæ, it would seem that the vital principle was equally diffused throughout every part of their fragile substance, which the slightest violence is sufficient to break up into pieces; indeed it is not uncommon to find the surface of the sea covered with fragments of their bodies, on which the locomotive cilia may still be seen in rapid action, producing, by their decomposition of the light, a splendid iridescent appearance.

(313.) The capacious cavity that occupies almost the entire length of the body of the Beroë, and communicates freely with the exterior through the inferior orifice, is perfectly smooth internally, and constitutes a kind of wide pharyngeal sac, at the bottom of which is situated a transverse aperture guarded by two thickened lips, the texture of which is firmer than that of the rest of the body. These lips only come in contact with each other near the centre of their free margins, and consequently leave on each side a gaping orifice. The cavity that they thus partially close is very small, and evidently corresponds with the central stomach of the discophorous Medusæ, and in like manner constitutes a central reservoir, from whence the vascular system is derived.

(314.) The digestive receptacle is filled with a fluid that is continually in movement, and which may be seen to pass into two lateral tubes that soon each divide into four branches and, arriving at the surface of the body, terminate in eight longitudinal canals that convey the contained fluid to the cilia, which latter organs, as they are in constant vibration, appear to perform the functions of a respiratory apparatus. From the lateral parietes of each of the eight longitudinal costal canals there arise an infinite number of small vessels or transverse sinuses; these, after intercommunicating with each other, are lost in the surrounding parenchyma*. Arrived at the margin of the wide opening situated at the inferior extremity of the body, the eight longitudinal trunks terminate in a transverse annular canal that communicates in its turn with two vertical trunks much more deeply seated than the preceding vessels: these lateral vessels, mounting upwards, terminate in the stomachal cavity.

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* Milne-Edwards, Ann. des Sci. Nat. tom. xvi., 1841.

(315.) The vascular apparatus above described is filled with a fluid in constant circulation, in which may be perceived innumerable round colourless globules. The course of the current is directed from the inferior vascular ring through the eight superficial canals situated beneath the ciliated ribs towards the summit of the body, whence it subsequently descends in a contrary direction through the two deep-seated trunks above described into the annular vessel, thus completing the circulatory round. The movement of the circulating fluid is tolerably rapid; nevertheless no traces appear of any central organ of impulsion, neither do the vessels exhibit the slightest contractility; in some of the larger trunks, however, the presence of cilia is distinctly perceptible, by the agency of which the circulatory current is produced.

(316.) From the researches of Milne-Edwards, it appears that the vascular system of the Beroëform Acalephs communicates with the exterior by means of emunctory canals analogous to the anal tubes situated on the margin of the disk in *Medusa aurita*, described above.

In *Beroë Forskahlii*, Milne-Edwards was enabled to assure himself of the existence of two such outlets, situated not at the inferior margin of the body, as in other Acalephs, but at its upper extremity. When this portion of the animal is fully extended, it frequently occurs that a little ampulla suddenly makes its appearance on one side or the other of the terminal fossa, which, quickly increasing in size, exhibits in its interior movements of rapid rotation; then, suddenly opening at its summit, it discharges its contents and immediately disappears, leaving no traces of its excretory functions except a minute pore, which is easily distinguishable. These excretory ampullæ communicate with the gastric cavity that forms the central reservoir of the vascular apparatus, and are evidently emunctories through which feculent matters are expelled.

(317.) The body of the Beroës has generally been described as having the form of a bag open at both ends,—a mistake which is explicable from the circumstance that, when the animal is not completely unfolded, its superior extremity is retracted and puckered up in such a manner as to give the appearance of a wide orifice placed opposite to that which occupies the inferior extremity: this appearance, however, is deceptive; for if one of these Acalephs is carefully examined while swimming freely in its native element, it becomes evident that the supposed upper orifice is only a deep cavity the bottom of which is furnished with a delicate contractile arborescent fringe, in the centre of which is situated a little pyriform papilla, regarded as constituting an ocular apparatus.

(318.) This oculiform speck, which is situated immediately in the axis of the body, presents, at its base, a globular spot of a red colour and granular appearance, in which are contained numerous minute crystalline corpuscles. The whole apparatus is immediately connected with a minute rounded mass, apparently of a ganglionic character, from which, in some genera, filaments are distinctly seen to issue.

(319.) In *Lesueuria*, for example, on carefully examining the bottom of the wide excavation that exists at the anterior extremity of the egg-shaped animal, four mammillated processes are apparent, each occupying the median line of one of the four principal lobes; and in the midst of these is seen an oculiform tubercle, situated precisely in the axis of the body, which is remarkable for its bright red colour. It is of a spherical shape, and presents a granular surface similar to that of the brilliant red spots distributed around the margin of the disk in the Medusæ, which Ehrenberg designates the eyes. Immediately beneath the oculiform spot is situated a subpyriform body, which is apparently of a ganglionic nature; its substance is more opake than that of the neighbouring tissues, and from it proceed a great number of filaments, apparently of a nervous character. These form four fasciculi, which run obliquely downwards towards the inferior and external margin of the principal lobes of the body: some very delicate filaments appear to terminate near the base of the accessory lobes; but the greater number are continued as far as the row of filiform appendages situated near the margins of the principal lobes, many of them apparently giving off ramifications in their course. Moreover, besides the above, a small longitudinal filament may be traced along the middle of each of the ciliated zones, probably of a nervous character, and which give origin to a multitude of little filaments that are distributed in a very regular manner, in fasciculi, beneath each of the little transverse ridges whereupon the vibratile fringes are attached, as well as to the mid-spaces intervening between them: it would even seem that there is a little ganglion at the origin of each of these ciliary branches; but whether this be the case or not is doubtful. At the upper extremity of the body, the vertical or ciliary filaments are prolonged beyond the ciliated ridges, and becoming united in pairs, run towards the central ganglion situated beneath the oculiform spot, with which, in all probability, they communicate.

(320.) From the above description it will be evident that the nervous system of *Lesueuria* differs widely in its arrangement from that supposed by Dr. Grant to exist in *Cydippe**, resembling more the arrangement of the nerves in the Tunicated Mollusca, with which the Beroïdæ present many natural affinities.

(321.) The arrangement of the generative system in the Beroëform Acalephæ is very imperfectly understood; or perhaps we ought rather to say that nothing is satisfactorily known concerning this part of their economy. M. Delle Chiaje* states that, upon the inner surface of each of the eight ciliated ribs, there is discoverable a longitudinal oviduct, to both sides of which are appended bunches of ovules,—an observation the accuracy of which is doubted by Milne-Edwards, who finds, indeed, on each side of the ciliated bands a multitude of little racemose bunches, of a rose colour, having the appearance of ovaria, but to whom it seemed that these bunches were contained in the substance of the walls of the body, and were simply dilatations of the lining membranes of the sub-ciliary vascular canals, which, instead of communicating with a common oviduct, opened into the vessels themselves.

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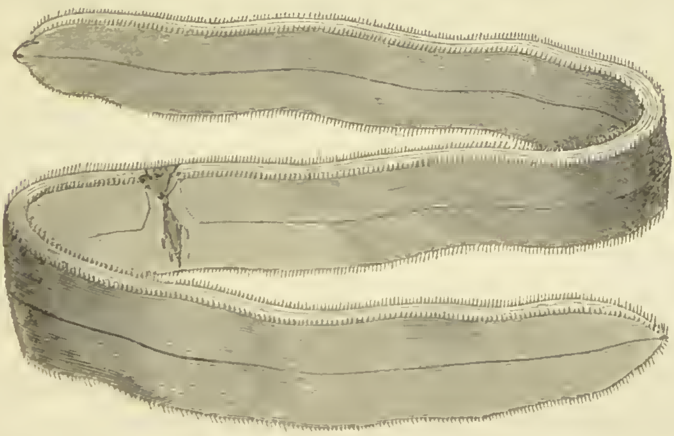
* Dr. Grant's figure of the nervous system as he supposed it to be arranged in *Cydippe pileus*, is given in a preceding page, fig. 57, 2.

(322.) From the researches of Will†, it would appear that these Acalephs are hermaphrodite, the generative apparatus consisting of elongated utricles, the testes being situated on one side and the ovaria on the other. Both sets of organs are described as having a nodulated appearance, and from the nodulated part of each passes off an excretory duct, which runs towards the mouth; but the terminal openings of these canals have not been made out. In Professor Grant's description of *Cydippe pileus*, of which a figure is given above (fig. 58, 1), the ovaries are said to consist of two lengthened clusters of small spherical gemmules of a lively crimson-red colour, extending along the sides of the alimentary canal. It is evident, therefore, that further knowledge relative to this department of the economy of the Beroës is still a desideratum in science.

(323.) The *Cestum Veneris* (fig. 59) is nearly allied to the *Beroë* in the arrangement of its nutritive apparatus, notwithstanding the difference of form observable in these Ciliograde Medusæ. In *Cestum*, the digestive cavity, which is exceedingly short in comparison with the

Fig. 59.



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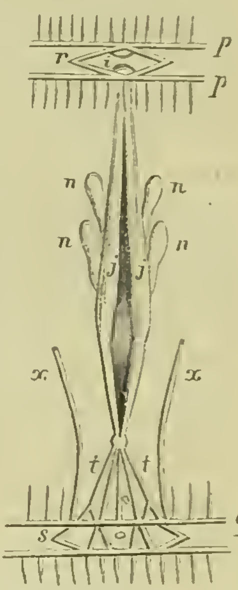
* Mem. sulla storia e anatomia degli Animali senza Vertebre, tom. iv. p. 12.

† Horæ tergest. p. 38. tab. 1. figs. 22, 23.

length of the animal, passes transversely across the body in a straight line from one side to the other, as represented in the engraving; but the details of its structure, and the nature of the vessels arising from it, will be best understood by a reference to the enlarged diagram of these parts given in the next figure (fig. 60). The mouth, *i*, is a rhomboidal depression, seen near the centre of the body, between the two lateral rows of locomotive cilia, which extend from one end of the animal to the other. From the mouth arise two tubes, *j j*, which terminate in a globular cavity common to both (these would seem to constitute the digestive apparatus); and a straight narrow tube, *o*, prolonged to the opposite margin of the body to that which the mouth occupies, may be regarded as an intestine through which the residue of digestion is discharged. From around the oral extremity of the stomach, and from the globular cavity in which the two principal canals terminate, arise vessels, *t t t*, which diverge so as to form a cone, at the base of which they all empty themselves into two circular canals, one surrounding the mouth, and the other encircling the anal aperture, which precisely correspond with the vascular rings already described in the *Beroë*; and, from these, four long vessels, or branchial arteries as they might be termed, *p p*, *q q*, are prolonged beneath the four ciliated margins all around the body. But besides these four nutritive vessels, two others, *x x*, arise from the anal ring, which run inwards towards the centre of the animal, and afterwards assuming a longitudinal direction, serve to distribute nourishment to the median portions of the animal. The cæca, or blind tubes, *n n*, appended to the intestine, may possibly furnish some secretion useful in digestion, although perhaps we are scarcely warranted in saying decidedly that they are biliary organs*.

Fig. 60.



Alimentary apparatus of *Cestum*.

(324.) Extraordinary as must appear the powers which the Acalephæ possess of seizing and dissolving other creatures apparently so disproportioned to their strength and the delicate tissues which compose their substance, there are other circumstances of their history equally remarkable, which, in the present state of our knowledge, are still more inexplicable. If a living Medusa be placed in a large vessel of fresh sea-water, it will be found to secrete an abundant quantity of glairy matter, which, exuding from the surface of its body, becomes diffused through the element around it so copiously, that it is difficult to conceive whence materials can be derived from which it can be elaborated. Of the origin of this fluid we are ignorant, although certain glandular-looking granules, contained in the folds of the pedicle, have been looked upon as connected with its production.

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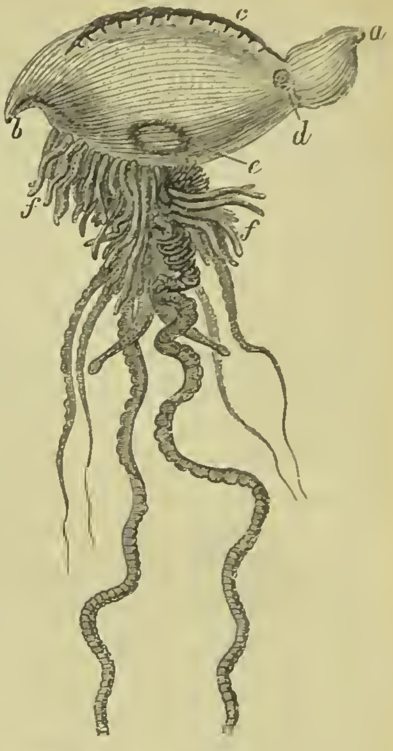
* Delle Chiaje, Memorie per servire alla storia degli Animali senza Vertebre del regno di Napoli. 4to, 1823-1825.

(325.) We are equally at a loss to account for the production of the irritating secretion, in which the power of stinging seems to reside; but it is observed that the tentacula seem to be more specially imbued with it than other parts of the body. Perhaps the most remarkable property of the Acalephæ is their phosphorescence, to which the luminosity of the ocean—an appearance especially beautiful in warm climates—is principally due. We have more than once witnessed this phenomenon in the Mediterranean; and the contemplation of it is well calculated to impress the mind with a consciousness of the profusion of living beings existing around us. The light is not constant, but only emitted when agitation of any kind disturbs the microscopic Medusæ which crowd the surface of the ocean: a passing breeze, as it sweeps over the tranquil bosom of the sea, will call from the waves a flash of brilliancy which may be traced for miles; the wake of a ship is marked by a long track of splendour; the oars of your boat are raised dripping with living diamonds; and if a little of the water be taken up in the palm of the hand and slightly agitated, luminous points are perceptibly diffused through it, which emanate from innumerable little Acalephæ, scarcely perceptible without the assistance of a microscope. All, however, are not equally minute: the Beroës, in which the cilia would seem to be most vividly phosphorescent, are of considerable size; the *Cestum Veneris*, as it glides rapidly along, has the appearance of an undulating riband of flame several feet in length; and many of the larger Pulmonigrade forms shine with such dazzling brightness, that they have been described by navigators as resembling "white-hot shot," visible at some depth beneath the surface. This luminousness is undoubtedly dependent upon some phosphorescent secretion; but its nature and origin are quite unknown.

(326.) Physograda.—In the third division of Acalephæ, denominated by Cuvier "Acalèphes Hydrostatiques," the body is supported in the water by a very peculiar organ, or set of organs, provided for the purpose. This consists of one or more bladders, capable of being filled with air at the will of the animal, which are appended to the body in various positions, so as to form floats of sufficient buoyancy to sustain the creature upon the surface of the sea when in a state of distension, but, when partially empty, allowing it to sink and thus escape the approach of danger. In *Physalia* (fig. 61), known to sailors by the name of the "Portuguese man-of-war," the swimming-bladder is single, and of great proportionate size, so that when full of air it is exceedingly buoyant, and floats conspicuously upon the waves. The top of this bladder bears a crest, *c*, of a beautiful purple colour, that, presenting a broad surface to the wind, acts as a sail, by the assistance of which the creature scuds along with some rapidity. The air-bladder is endowed with a considerable power of contraction, and when carefully examined, two orifices are observable, one at each extremity, *a*, *b*, through which, upon pressure, the contained air readily escapes—a provision for enabling the creature to regulate its specific gravity at pleasure, and when alarmed, at once to lessen its buoyancy by diminishing the capacity of its swimming-bladder, and to sink into the waves. The nature of the air with which the little voyager distends its float has not been accurately determined; but it is undoubtedly a secretion furnished at pleasure when at a considerable distance from the surface, although the mode of its production is still unknown.

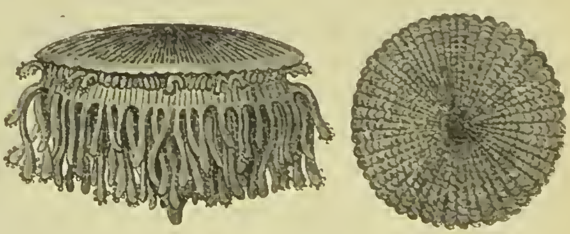
Fig. 61.



Physalia. *a b*, vesicular float; *c*, crest; *d*, orifice; *e*, nucleus; *ff*, inferior appendages.

(327.) Cirrigrada.—The Cirrigrade Acalephæ form a very remarkable family, peculiarly distinguished by the possession of an internal solid support, or skeleton, secreted in the substance of their soft and delicate bodies. In *Porpita* (fig. 62), this consists of a flat plate of semicartilaginous texture (fig. 62, 2), evidently deposited in thin secondary laminæ, which gradually increase in size as the animal advances in growth, the inferior being the largest and last formed. When examined after its removal from the body, this fragile skeleton is seen to be extremely porous or cellular; and the pores being filled with air, it is specifically lighter than water—a circumstance that may contribute to the buoyancy of the creature even when alive.

Fig. 62.



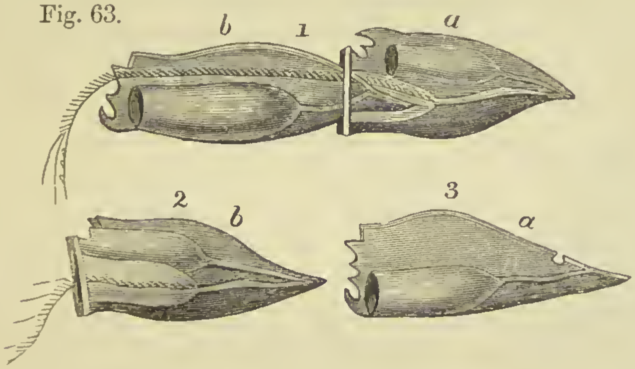
Porpita.

(328.) The lower surface of *Porpita* is furnished with numerous appendages called *cirri*, whereof some appear to be organs of prehension.

but perform also the office of oars, which, in this species, are the principal agents in progression; yet in other Cirrigrada, as *Velella* and *Rataria*, besides the horizontal lamella that forms the whole skeleton of *Porpita*, there is a second subcartilaginous plate, rising at right angles from its upper surface, and supporting a delicate membranous expansion, that rises above the water and exposes a considerable surface to the wind, so as to form a very excellent sail. To perfect so beautiful a contrivance, in *Rataria* the crest is found to contain fibrous bands, apparently of a muscular nature, by the contractions of which the sail can be depressed or elevated at pleasure.

(329.) Diphyea.—The last family of the Acalephæ derives its name from the singular appearance of the creatures composing it; each animal, in fact, seems to consist of two portions (*a*, *b*, fig. 63, 1, 2) so slightly joined together, that it is by no means easy to understand the nature of the connexion between them.

Fig. 63.



Diphyes Bory.

(330.) The body of these strangely-organized beings is composed of two polygonal, subcartilaginous, transparent pieces placed one behind the other, the posterior division being implanted more or less deeply into the anterior. These two divisions are invariably more or less dissimilar from each other; nevertheless they offer this circumstance in common, that they are excavated internally by a deep cavity, which opens externally with a wide orifice of regular shape, although differing in form in each division. To these details of their general appearance must be added the existence of a long filiform appendage, which issues from the upper cavity of the anterior cartilaginous portion, and which was regarded by Cuvier as the ovary.

(331.) On more minute examination, there is recognizable in the anterior division a visceral mass called the nucleus, which is made up of a proboscidiform œsophagus, terminated by a sucker-like mouth, and continuous with a stomachal cavity, whereunto are appended hepatic follicles of a greenish colour, and sometimes a little vesicle filled with air.

(332.) Besides the above structures there may be remarked, towards the lower part of the body, another glandular-looking mass, probably the ovary, which is connected with the long (ovigerous ?) filament above alluded to. The *nucleus* is contained in a proper cavity, generally distinct from the large excavation that forms the locomotive apparatus, and is connected by filaments, apparently of a vascular character, to the soft parts within the body. It has been already remarked that this latter division is excavated by a large cavity that extends nearly throughout its entire length; from the bottom of this cavity arises a prolongation, probably of a vascular character, which embraces the root of the (ovigerous ?) filament, and is apparently connected with the nucleus, from which, however, it may be detached by the slightest effort.

(333.) The bodies of these strangely-constructed creatures are so extremely transparent, that their presence is discoverable with great difficulty even in small quantities of sea-water. They are generally met with at a great distance from land, abounding more especially in the seas of tropical climates. They swim with great facility, their anterior or nuclear extremity being directed foremost; while the water taken into their bodies, being forcibly ejected, by the contractions of their subcartilaginous parietes, through the wide apertures opening backwards, propels them through their native element.

(334.) Whilst exercising this mode of locomotion, the long slender filament above alluded to is extended behind, being partially lodged in a groove excavated in the posterior division of the natatory organ. It varies considerably in length, being highly contractile, so much so, indeed, that it is sometimes completely withdrawn into the body; and its structure is further remarkable from the circumstance that throughout its whole length it is furnished at regular intervals with minute suckers*. But the true nature of this organ is very imperfectly known: most probably it will be found to be analogous in its real character to the proligerous apparatus of the *Salpæ*, to be described hereafter; indeed. such is the evident relationship between the Diphyea and the Salpoid Tunicata, that it is very doubtful whether they ought not to be classed as members of that group.

CHAPTER VII.

HELMINTHOZOA.

(335.) THE HELMINTHOZOA, embracing the vast class of parasitic worms, may be conveniently divided into two groups. First, those which live as parasites—the ENTOZOA, and secondly, those which are free and have an independent existence, as is the case with many of the TREMATODE WORMS and the TURBELLARIÆ.

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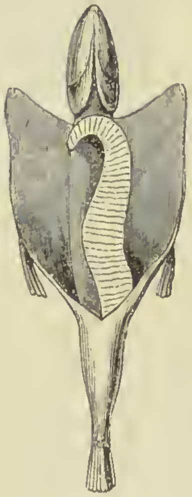
* Quoy et Gaimard, Voy. de l'Astrolabe.

(336.) The Entozoa, as the name implies, are nourished within the bodies of other animals, from the juices of which they derive their sustenance. It may naturally be supposed that, living under such circumstances—deprived of all power of locomotion, debarred from the influences of light, and absolutely dependent upon the fluids wherein they are immersed for nutriment—the Entozoa have little occasion for that elaborate organization needful to animals living in immediate communication with external objects.

(337.) We find, therefore, among these creatures, certain races whose structure is of the simplest character possible, in adaptation to the circumscribed powers of which they are capable. Yet, however apparently insignificant some of them may appear, they not unfrequently become seriously prejudicial to the animals wherein they are found, by the prodigious numbers in which they exist, or from their growth in those organs more especially essential to life; and not a few of them, from their dimensions alone, sometimes prove fatal, as may be supposed from a mere inspection of the annexed figure (fig. 64), representing an Entozoon developed in the abdominal cavity of a fish.

Fig. 64.

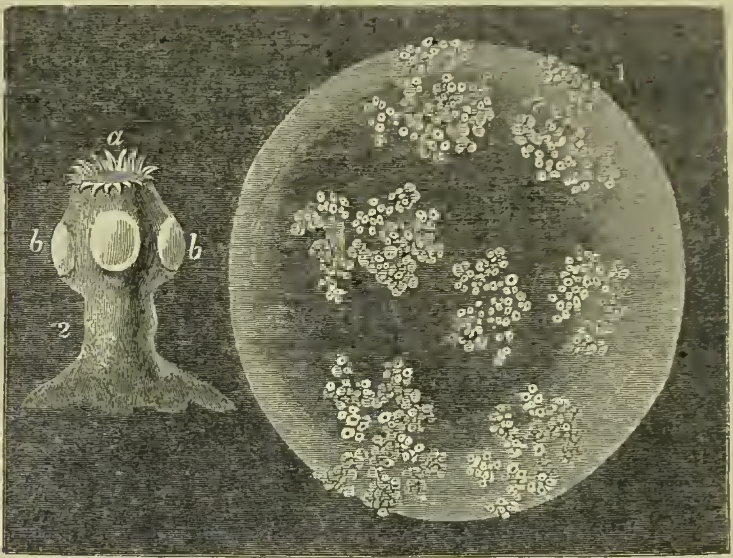


Ligula simplicissima in the abdominal cavity of a Minnow.

(338.) There are probably no races of animals which are not infested with one or more species of these parasites, from the microscopic infusoria up to man himself; and sometimes several different forms are met with in the same species, to which they would appear to be peculiar; nay, in some cases the Entozoa would seem themselves to enclose other species parasitically dwelling in their own bodies. Neither is their existence confined to any particular parts; they are met with in the alimentary canal, in the liver, the kidneys, the brain, the arteries, the bronchial passages, the muscles, the cellular tissue, and, in fact, in almost all the organs of the body.

(339.) The *Cystiform Helminthozoa*, generally known by the name of *Hydatids*, are the simplest in structure; and with these, therefore, we shall commence our inquiry into the economy of these creatures. The *Cœnurus cerebralis* (fig. 65), one of the most common, occurs in the brain of sheep, and is the cause of a mortal disease but too well known to the farmer; it is likewise occasionally developed in other ruminating quadrupeds, and, by partially destroying the cerebral substance, soon proves fatal. This Entozoon, represented in the figure of ordinary size, consists of a delicate transparent bladder, the walls of which, during the life of the creature, are visibly capable of spontaneous contractions on the application of stimuli. To this bladder, or common body, are appended numerous heads, which are individually furnished with an apparatus of hooks and suckers (fig. 65, 2, *a*, *b*), calculated to fix them to the surrounding tissues.

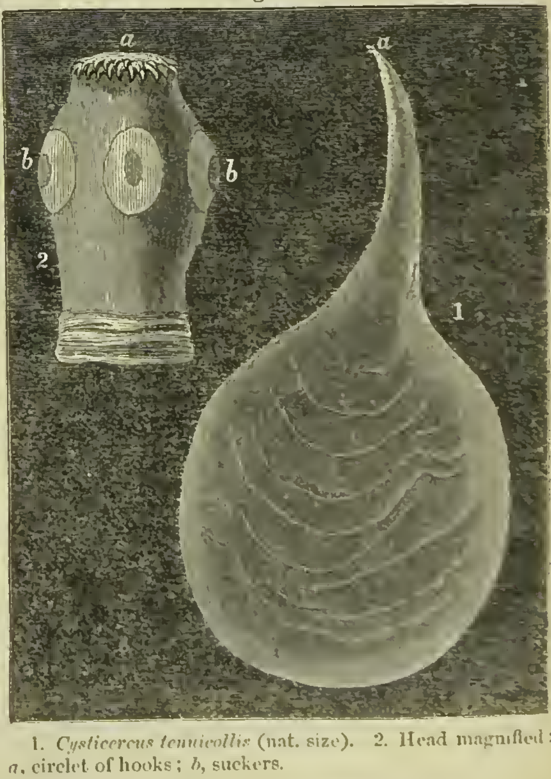
Fig. 65.



1. *Cœnurus cerebralis* (nat. size). 2. One head magnified: *a*, oral circlet of hooks; *b*, suckers.

(340.) The *Cysticerci*, or common hydatids, agree in the main features of their structure with the Cœnurus, but are provided with only one head or oral orifice (fig. 66, 2). These animals are found in almost all the viscera of the body, and not unfrequently, especially in pigs, exist in great numbers, not only in the liver, which is their most usual seat, but in the cellular texture of the muscles, and even in the eyes themselves. The human frame is not free from their intrusion; and when they abound, serious consequences frequently result from their presence.

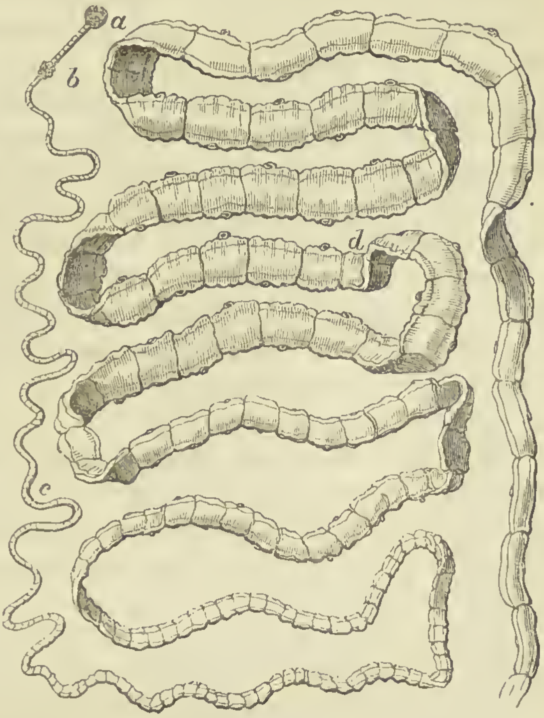
Fig. 66.



1. *Cysticercus tenuicollis* (nat. size). 2. Head magnified: *a*, circlet of hooks; *b*, suckers.

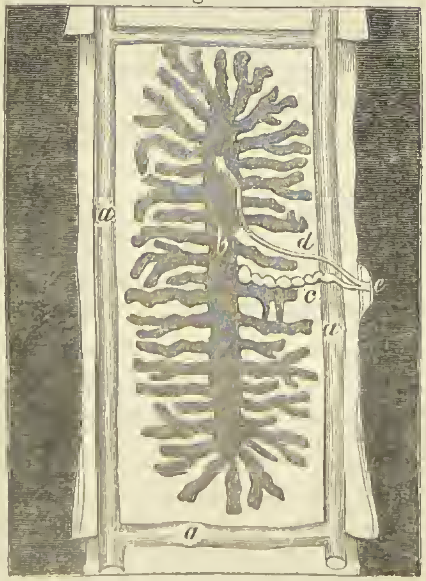
(341.) Cestoidea.—The *Tæniæ*, or tape-worms, are among the most interesting of the Sterelmintha, whether we consider the great size to which they sometimes attain, or their singular construction. Several species of these worms infest the human body, and many other forms of them are met with in a variety of animals. They are usually found in the intestinal passages, where, being amply provided with nutritious aliment, they frequently grow to enormous dimensions, being not unusually twenty or thirty feet in length; and some have been met with much longer: it is therefore manifest how prejudicial their presence must prove to the health of the animals in which they reside; and we are little surprised at the emaciation and weakness to which they generally give rise.

Fig. 67.



Tænia solium: *a*, head; *b*, *c*, *d*, segments of the body.

Fig. 68.



Immature segment of *Tænia solium*: *a*, lateral canals; *b*, ovary; *c d*, accessory glands; *e*, lateral sucker.

(342.) The *Tænia solium*, the species most usually met with in the human subject, at least in our own country, is that selected for special description. The body of this creature consists of a great number of segments united together in a linear series (fig. 67): the segments which immediately succeed to the head (*a*) are very small, and so fragile that it is rarely that this part of the animal is obtained in a perfect state; they gradually, however, increase in size towards the middle of the body (*d*). The first joint of the Tænia, generally called the head, differs materially in structure from all the rest. This segment in the *Tænia solium*, when highly magnified, is found to be somewhat of a square shape; in the centre is seen a pore that has been considered to be the mouth, surrounded with a circle of minute spines, so disposed as to secure its retention in a position favourable for imbibing the chyle wherein it is immersed. Around this apparatus are placed four suckers, which are no doubt additional provisions for the firm attachment of the head of the worm. In other Tæniæ the structure of the first segment is variously modified: thus, in *Tænia lata* the central pore has no spines in its vicinity; in *Bothriocephalus* there are only two longitudinal sucking disks; in *Floriceps* these are replaced by four proboscidiform prolongations, covered with sharp recurved spines, which, being plunged into the coats of the intestine, form effectual and formidable anchors; yet the intention of all these modifications is the same, namely, to retain the head in a position adapted to ensure an adequate supply of nutritious juices.

(343.) The alimentary canal seems to be represented by a double tube, which may be traced through the whole length of the body, without any other perceptible communication with the exterior than the minute pore in the centre of the head: at the commencement of every segment, however, there is a cross-branch, which communicates with the corresponding tube of the opposite side (fig. 68, *a*), so as to facilitate a free distribution of the nutrient fluids*. In some species a delicate vascular network is perceptible in the parenchyma of the body, which may likewise be connected with the nutritive function.

(344.) The reproductive organs in the mature segment or *Proglottis* of a tape-worm, each of which may be considered as an adult animal, consist of a male and of a female apparatus—these two sets of organs being completely distinct from each other.

The male apparatus consists of a testis, a vas deferens, and an intromittent organ, the last of which is lodged in a special sac or pouch.

The testis (fig. 69, *a a*, *b*) occupies the middle of the anterior portion of the body, and is of a whitish colour, owing to the spermatozoa contained in its interior. It is composed essentially of a long cæcal tube, folded upon itself in close convolutions, and terminating in the vas deferens (*c*), which reaches to the base of the intromittent organ.

The penis (fig. 69, *d*), called also by authors *cirrus* and *lemniscus*, is very variable in its form in different genera; in its real structure, however, it is merely a prolongation of the vas deferens, just as the latter tube is a continuation of the testis.

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* Professor Van Beneden denies the existence of the central aperture or mouth, or that the two lateral longitudinal canals with their intercommunicating trunks constitute an alimentary system; on the contrary, he regards these tubes as secerning organs, the secretion of which is discharged from the terminal segment of the body through a *foramen caudale*.

In its size it varies considerably; it consists of two muscular coats invaginated one within the other, and unrolls itself like the finger of a glove, until it acquires its full length. The external surface, which is internal when in a state of repose, is covered with minute asperities or rough points; when fully retracted, it is lodged in the pouch, *e*.

(345.) The female generative system is composed of an ovary, which produces the germ (germigène), of an organ which secretes the vitelline globules (vitelligène), of ducts from these two organs, and of a matrix, a copulative vesicle, vagina, and vulva.

(346.) It seems to have been by no means a rash supposition on the part of Siebold, that in some Entozoa there might exist a double set of glands for the production of the ova, one appropriated to the formation of the germ, the other to the secretion of the vitellus. In the Cestoid forms, according to Van Beneden, the proper ovary or germigène (fig. 69, *i*) is situated at the posterior part of the body, occupying about one-third or one-quarter of its width. This organ is double, being exactly repeated on the right and left of the median line, the two being united by a central commissural canal*: when empty, the presence of this organ is discoverable with difficulty, on account of its extreme delicacy. Its appearance varies much: sometimes it is a bag surrounded with slight depressions (*culs-de-sac*); sometimes the whole viscus is divided into lobes, and has the appearance of an ordinary gland, whilst occasionally it is entirely made up of long cæcal tubes united together, and opening at the same point.

Fig. 69.

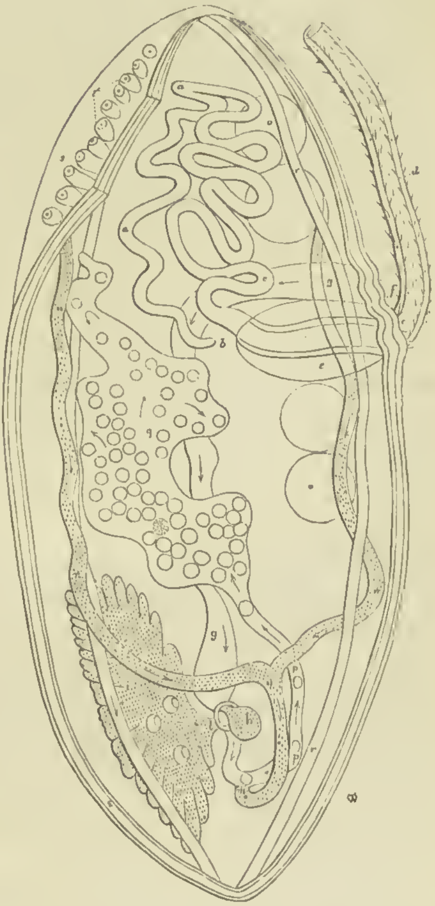

Diagram representing the fully-developed generative system of the *Proglottis* of a Cestoid Entozoon (after Van Beneden). *a*, testis; *b*, commencement of ditto; *c*, vas deferens; *d*, penis; *e*, sac of the penis; *f*, orifice of vagina; *g*, vagina; *h*, copulative vesicle; *i*, germigenous organ, or ovary (represented on one side only); *l*, germiduct; *m*, point at which the vitelline globules enter the germiduct; *n*, vitelligenous organ, or vitelliduct; *o o*, transparent vesicles, developed at a very early period; *p*, oviduct; *q*, matrix; *r*, longitudinal canals; *s*, the skin; *t*, cutaneous glands.

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* It is represented in the figure upon one side only, to avoid confusion.

On the sides of the body, extending nearly its whole length, are two slender and slightly flexuous tubes (fig. 69, *n n*), whose presence it is difficult to detect when in an empty condition, but which generally contain in their interior vitelline globules closely aggregated together, which by the peristaltic movements of the tube, aided by ciliary action, are forced onward from before to behind. The two vitelligenous tubes ultimately unite to form a common canal (*n*), situated near the median line, through which the vitelline globules enter the germiduct at the point marked *m*. On passing the opening of this canal, the germ becomes suddenly invested with a layer of vitelline globules, and, being thus transformed into an ovum, is carried onwards through the flexuous canal, or proper oviduct (*p*), into the matrix (*q*), becoming invested in its passage through the oviduct with an outer covering that represents the egg-shell.

The *matrix* (*q*) thus receiving a continual supply of ova, becomes gradually distended, until it occupies almost all the interior of the body, and branches out in different directions into cæcal pouches at points where the least resistance is offered, until finally the skin of the proglottis becoming as tightly distended as the matrix, both are ruptured, and the ova escape in this artificial manner. The *vagina* (fig. 69, *g g*) is a large canal, having, like all the organs belonging to this apparatus, distinct parietes. It commences externally (*f*) in the immediate vicinity of the male organ, penetrates to the centre of the body, and, bending at an angle, makes its way backwards to the space that separates the two ovaria (germigenous organs, *i*). Its length is invariably in correspondence with that of the penis of the male apparatus. At the extremity of the vagina is situated the *copulative sac* (*h*), a small vesicle with very delicate parietes, the contents of which abound in spermatozoa.

Such being the anatomical arrangement of the different parts of this somewhat complex apparatus, it now remains to take a brief survey of their physiological import in the performance of the generative function. In the living Entozoa it is sometimes not difficult to see the germigenous and the vitelligenous organs opening into a common canal, and each of them pouring their product into its cavity; and if a specimen is selected in which the parts are in full activity, and the compression used be such as to render the organs transparent without putting a stop to their action, the germs may be seen to arrive, one by one, at regular intervals, before the opening of the vitelligenous organ, which, contracting forcibly, expels a certain quantity of the vitelline substance, in which the germ becomes enveloped, having previously, on passing the orifice of the copulative sac, become impregnated by contact with the spermatozoa therein contained. As the vivified ovum advances onwards it receives its outward envelope, arrives in the matrix, and is there retained until birth is accomplished by the destruction of the animal.

A question has often arisen in relation to the manner in which the act of copulation is effected in animals presenting this remarkable hermaphrodite condition of the generative system—a question to which Professor Van Beneden has been able to give a satisfactory solution. In a specimen of *Phyllobothrium luca*, he had ocular demonstration that the individual was self-fecundating. Its penis became unrolled, and passed immediately through the vulva into the vagina, into which it was deeply inserted. Active peristaltic movements of the vaginal tube were very manifest, and spermatozoa were seen abundantly in its interior, these being subsequently conveyed by peristaltic action into the copulatory pouch. The penis, after some considerable time, is withdrawn, returns into its pouch, and all the organs assume their previous condition.

(347.) In studying the progressive development of the egg in the Tæniæ and other Cestoid worms, it is only necessary to remember that all the ova contained in the same segment are of the same age, and that the age of the segments increases progressively, from the head to the opposite extremity of the elongated body, to enable the observer to select ova in any stage of their development in order to submit them to examination under the microscope.

(348.) In their general structure, the eggs of the Tænioid Entozoa are similar to those of the other classes of Invertebrate animals; and the segmentation and breaking-up of the yelk proceed exactly in the same manner.

(349.) On arriving at maturity, however, a series of phenomena of the highest possible interest begin to develope themselves, which we will proceed to describe with as much conciseness as the subject will allow*. The worm, when it emerges from the egg, instead of being composed of a series of segments, consists simply of the first segment, or *head*, as it is called, of the compound worm, variously armed with hooks, suckers, or bothria, according to the genus, to which is appended a short caudal extremity, wherein but slight traces of any internal organ are apparent. In this condition it has received the name of *Scolex*, and may be regarded as a sort of root from which all the rest of the animal is developed, much in the same way as the *Planulæ* of the Acalephæ are segmented off from their Hydra-like parent (§ 304). In this condition the "Scolex" exists for some time, and in some instances, as, for example, in the *Tetrarhynchi*, clothes itself in a kind of sheath formed by a mucous exudation derived from the surface of its body.

(350.) We have already pointed out the similarity of structure that exists between the armature of the "head" of the Cysticercus (fig. 66) and that of the Tænia (fig. 67); but the reader, from a comparison of the two figures, would scarcely be prepared to expect that the one was the *Scolex* of the other. Siebold had, indeed, satisfied himself that the arrangement of the horny circlet of *Cysticercus fasciolaris*, found in the liver of the mouse, entirely corresponded with that of *Tænia crassicollis*, that inhabits the intestines of the cat. If young Tænias and Cysticerci be carefully examined, and compared with other forms, it is satisfactorily seen that the Cysticercus is merely the Scolex from which a Tænia may be developed, and that its vesicular portion corresponds exactly with the similar vesicles of some Tetrarhynchi in a like state of development. A Tænia, says Van Beneden, might probably very well acquire its complete development, without assuming the vesicular form, as is proved by the Paradoxical Tænia; but, for that, it would be necessary that the germ should be deposited in an intestinal tube. The same is the case with the *Tetrarhynchi*: here also the body becomes quite out of proportion to the size of the head whilst the germ remains amongst the peritoneal folds of the fishes in which they are found, just as the Cysticerci do whilst imbedded in the peritoneum or amongst the muscles. The Scolex, when fully formed, has its own individual development arrested at this point; but it now begins to give off buds, of which the body (*Strobile*) of the Entozoon is composed.

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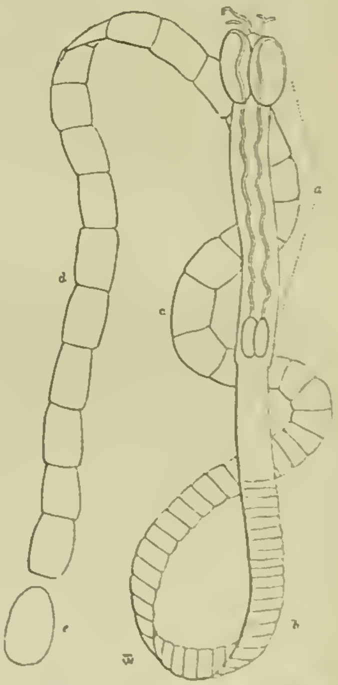
* *Vide* "Recherches sur les vers Cestoïdes," par P. J. Van Beneden, Nouveaux Mém. de l'Académie de Bruxelles for 1850.

(351.) The Scolex, therefore, in this stage of development is synonymous with the "head," or, as it might as well be called, the "root" of the worm; and as long as this root, head, or Scolex remains unexpelled from the body, it will continue to give origin to fresh segments or joints, *ad libitum.*

(352.) Gradually the tail of the Scolex, or the body of the worm, is developed; and as soon as this has attained a certain length, transverse markings begin to make their appearance, segments are formed, separated from each other by slight indentations, and the internal organs appropriate to each segment are progressively evolved. When the segments have attained to maturity, or, in other words, when the gemma has grown into an adult worm (*Proglottis* of Van Beneden), the indentation separating each from the one preceding it increases in depth, until, being reduced to a mere pedicle, the segments are successively thrown off as so many distinct animals. From the above account, therefore, it is evident that the last,

Fig. 70.



a, Scolex; *b c d*, Strobile; *e*, Proglottis.

or caudal, segment is always the oldest, the newly-formed segments continually pushing the others from before backwards.

(353.) Most frequently the mature segment or *Proglottis* is detached, as stated above, and becomes an independent worm: nevertheless this probably does not invariably happen, some apparently remaining permanently connected together, and laying their eggs without having enjoyed a separate existence, as is the case in various forms of Ascidians and Polyps.

(354.) While the segments of the Strobile remain conjoined, they seem to enjoy a complete community of life and of movement. Some species especially may be observed to become suddenly dilated in one region and contracted in another—these alternate movements, passing along the entire length of the animal, giving precisely the same appearance as is witnessed in many Annelidans when they make violent efforts for progression,—a circumstance which will readily explain how Tæniæ are frequently met with having their bodies tied in complicated knots—a very puzzling phenomenon to the older helminthologists.

(355.) The *Proglottis*, on becoming detached from the general community, is provided with all its organs; nevertheless its development becomes still further advanced: it even completely changes its shape; the angles of the segment become effaced, the whole body rounded, and its movements, moreover, more extensive: nay, as Van Beneden assures us, not only does the Proglottis continue to grow, but sometimes it becomes as large as the entire Strobile—a circumstance which frequently causes a Cestoid at this age to be mistaken for a Trematode Entozoon.

(356.) Many thousands of eggs must be produced from such multiplied sources of reproduction; and yet, how are they preserved and replaced in circumstances favourable to their development? Fortunately it is rare to meet with more than one of these creatures, at the same time, taking up a residence in the same individual; and, in fact, the species which has specially been the subject of our description is often called, *par excellence*, "the solitary worm," from this circumstance. Yet what becomes of the reproductive germs furnished in such abundance? Do they, as was the opinion of Linnæus, live in a humbler form in stagnant waters and marshes, until they are casually introduced into the body of some animal, where, being supplied profusely with food and placed in a higher temperature, they attain to an exuberant development? Or are the germs thus numerous in proportion to the little likelihood of even a few of them finding admission to a proper nidus? To these questions we can only reply by conjectures; and, interesting as the subject is, few are more entirely involved in mystery.

(357.) In some Tæniæ, as for example in *T. serrata*, which is found in the intestines of dogs, M. Dujardin has pointed out that the ova, instead of being, as Rudolphi supposed, more delicate and frail in their substance than the Entozoa themselves, are defended by envelopes so strong that, thus protected, they may be dispersed in prodigious numbers in various situations, and escape destruction until conveyed into a nidus proper for their development.

(358.) To form some idea of the number of ova furnished by a single Tænia of this species, it must be considered that it is furnished successively with at least two hundred segments, which in the aggregate will produce for each Tænia 25,000,000 of eggs. The mature segments are found loose in the intestine of the dog, and are able to move about with considerable quickness, creeping sometimes at the rate of three inches in a minute, by the contractions of which they are capable. If one of these be placed in a flask, or under a moist glass bell, they will soon begin to crawl about upon its surface, leaving a sort of milky track wherever they pass, in which, by the aid of a lens, innumerable eggs may be detected. Under these circumstances they will exist for several days, until they are entirely emptied of their ova and reduced to half their original bulk, when, their destiny being accomplished, they perish. Therefore it cannot be doubted that, when expelled naturally from the intestines of the animal in which they live, they are able to deposit their ova in a similar manner.

(359.) Many interesting facts relative to the development of the intestinal worms have been recently brought to light, and promise to lead to still more important discoveries. In 1840 M. Miescher announced to a meeting of naturalists at Bâle, the discovery that several genera of Entozoa undergo most extraordinary metamorphoses, whereby their form and character are completely changed. A *Filaria,* met with in a fish, became changed into a flat, oval, leaf-like worm, in fact a *Planaria* ; from the interior of the Planaria there subsequently issued a *Tetrarhynchus,* armed with four long proboscides; and lastly, the last-mentioned form probably gave birth to a *Bothriocephalus.*

(360.) Carrying out these observations, M. Van Beneden* has not only confirmed the doctrine, but added very materially to our knowledge on this subject, by ascertaining that the *Tetrarhynchus* undergoes no fewer than four distinct phases of development.

(361.) In the first phasis of its existence, the worm is more or less vesicular in structure, being armed with four suckers, and a sort of proboscis in the centre. It is possessed of extraordinary contractility; and in different species there are spots of black pigment, representing eyes. In this condition these worms have received from helminthologists the name of *Scolex* (*Scolex polymorphus* ; *Scolex Acalepharum*), Sars, *Tetrastoma Playfairii,* Forbes and Goodsir, *Dithyridium Lacertæ,* &c. These are more especially found in the pyloric cæca.

(362.) The second phasis is, perhaps, the most curious. In the interior of the *Scolex* there is formed a *Tetrarhynchus*, by a process of gemmiparous reproduction; and from the surface of tho latter a kind of viscid secretion exudes, which becomes solid, and forms a sort of sheath made up of concentric layers.

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* Ann. des Sc. Nat. 3 sér. x. p. 15.

(363.) In this state of development there is found a sheath formed of several layers, in the interior of which is a Trematode worm (*Amphistoma rhopaloides*, Ch. Le Blond); and in the interior of the latter may be perceived a *Tetrarhynchus*, which moves about vivaciously as soon as its prison is opened. This Tetrarhynchus has been regarded by naturalists as a parasite inhabiting the Trematode worm; M. Van Beneden believes it to be a moveable gemma (*bourgeon mobile*).

(364.) It is constantly, if not always, found in cysts formed at the expense of the peritoneum, in a great number of sea-fish—cod, trigla, conger, &c. In the third state of its existence, the Tetrarhynchus is free, but in all respects resembling that which was enclosed in the Trematode worm; in a short time, however, transverse lines become developed upon the posterior part of its body, segments are formed, and it becomes *Tænioid*. In this condition it has been named *Bothriocephalus*, or more recently *Rhynchobothrius*. It is found in the intestinal canal of the skate, among the first turns of the spiral valve.

(365.) In the fourth and last phase of its growth, it presents a more simple structure, the perfect animal performing the part of a tube destined to disseminate ova. In this condition it is nothing more than the last segment of the Tænioid form detached, in fact a *Proglottis*. In this condition it is found in the intestine of the skate, in company with the Bothriocephali: this is the mature or adult animal, provided with complete male and female sexual organs.

(366.) The adult Entozoon (the Proglottis loaded with eggs) is evacuated together with the fæces of the skate, and with its ova serves as food to fishes of small dimensions. The ova are developed either in the intestines or the intestinal cæca of the devourer, and if the fish which contains them happens to be swallowed by another fish, the development still proceeds in *its* alimentary canal, or the cæca thereunto appended. When arrived at the condition of a complete *Scolex*, after having perhaps passed through the stomachs of several fishes that have successively devoured each other, it perforates the intestinal walls and lodges itself in the peritoneum, in which situation it forms its sheath, and produces in its interior the "moveable gemma," from which is produced a *Tetrarhynchus*. The fishes containing the latter form are swallowed in turn by the voracious Rays and Sharks, and their flesh having been dissolved in the stomachs of their devourers, the Tetrarhynchus becomes free, and continues its growth in the intestines until the last forms (*Proglottis*) are complete, which alone are furnished with a sexual apparatus. Thus, from the production of the egg to the completion of the mature animal, these parasites are continually passing into the alimentary canals of new fishes; and it is only under such circumstances that they seem to attain their full development.

(367.) CYSTOIDEA.—*Transformation of Cystiform* Entozoa *into* Tæniæ. —The gradual transformation of *Cysticercus pisiformis* into the *Tænia serrata* has been established by feeding young dogs with the cystic parasites still enclosed in the cysts in which they are found in the omentum of rabbits*. The first effect produced upon the Entozoa thus enclosed in their cysts, after they have been swallowed, is the solution of the cysts by the gastric juice in the dog's stomach, after which the caudal vesicle of the *Cysticercus pisiformis* is attacked and destroyed by the same digestive agent, leaving nothing of it remaining but the whitish and rounded *Scolex*, which, passing through the pylorus, becomes attached to the walls of the duodenum, in which situation it has to await its subsequent growth. At the posterior end of the now tailless cyst-worm, the point at which the caudal vesicle was previously attached is distinctly indicated by a sort of cicatrix. Subsequently the growth of the Entozoon commences, its transverse wrinkles are multiplied, and in the course of a few days the body becomes divided into segments, which, at first very short, elongate and soon present the marginal generative pores. After a residence of twenty-five days in the intestines of the dog, the Tænia has attained the length of from 10 to 12 inches, and in three months 20 or 30 inches or more, at which time the posterior joints appear to be sexually matured, and the last segments (*Proglottides*) become detached. The ova enclosed in the ripe joints are seen to be completely developed, and contain in their interior the mobile embryo armed with its six hooklets.

It must now be an important task for helminthologists to trace the further development of the embryos produced from these eggs, in order to determine the mode of origin of the *Cysticercus pisiformis.*

(368.) The *Echinococcus veterinorum*, long considered as a distinct Entozoon, is in reality merely a hydatid cyst filled with the larvæ (*Scoleces*) of Tænioid worms; it occurs in the liver, the cavity of the abdomen, the heart, the voluntary muscles, and the ventricles of the brain of man,— in the liver, lungs, &c. of the ox, sheep, goat, ape, pig, &c. The walls of the true cysts consist of numerous concentric layers or plates, resembling those of colloid cells. The liquid existing within them is yellowish or reddish, and albuminous. The larvæ appear to the naked eye as minute white opake specks, varying in size from about $\frac{1}{300}''$ to $\frac{1}{100}''$ in length; they also vary greatly in form: when the head is retracted, they appear more rounded than when it is protruded. The hooks surrounding the anterior end of the body consist of a basal portion, an internal transverse blunt tooth, and a curved terminal portion or claw; they are about $\frac{1}{1500}''$ to $\frac{1}{1000}''$ in length. In some of the

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* *Vide* De Cysticercorum in Tænias Metamorphosi pascendo, experimenta in Instituto Physiologico Vratislaviensi administrata. Auctor G. Lewald: Berolini, 1852.

larvæ a kind of pedicle exists, by which they are attached to the walls of the cyst. In a quite recent state the larvæ have been seen swimming actively in the liquid of the cyst by means of cilia upon the surface of the body. They appear usually to be developed from the interior of the cyst; but, as Kuhn long since showed, they are sometimes produced by external gemmation: the contents produce a slight protrusion of a part of the wall of the cyst; the protruded portion enlarges, afterwards becoming constricted at the base, and at last probably separates from the parent, to become itself a parent in a similar manner. Hence it appears that the larvæ cannot be regarded as the parasites of the cyst, but must be viewed as arising from a partial segmentation of the contents of the parent. The *Echinococci* do not acquire their full development into *Tæniæ* unless they reach the alimentary canal. The cysts and their contents, including the *Echinococci*, undergo a kind of degeneration, becoming partially converted into fatty or calcareous matter, or the entire contents become amorphous and granular, the hooks remaining longest unaltered, but finally disappearing also*.

(369.) TREMATODA.—In the fluke, *Distoma* (*Fasciola*, Linn.) *hepaticum*, we have an Entozoon of more complex and perfect structure—one of those forms, continually met with, which make the transition from one class of animals to another so insensible that the naturalist hesitates with which to associate it.

(370.) The *Distoma* is commonly found in the liver and biliary ducts of sheep and other ruminants, deriving nourishment from the fluids in which it is immersed. The body of the creature, which is not quite an inch in length, is flattened, and resembles in some degree a minute sole or flat-fish. At its anterior extremity is a circular sucker or disk of attachment, by which it fastens itself to the walls of the cavity in which it dwells, as well as by means of a second sucker of similar form, placed upon the ventral surface of the body. In the annexed diagram (fig. 71) the posterior sucker has been removed in order more distinctly to exhibit the internal structure of the animal. The name which this Entozoon bears seems to have been given to it from a supposition that it possessed two mouths, one in each sucker, whereas the anterior or terminal disk (*a*) only is perforated, the other being merely an instrument of adhesion. The alimentary canal (*b*) takes its origin from the mouth as a single tube, but soon divides into two large branches, from which ramifications arise that are dispersed through the body, each terminating in a blind clavate extremity. These tubes, from being generally filled with dark bilious matter, are readily traced, even without preparation, or they may be injected with mercury introduced through the mouth.

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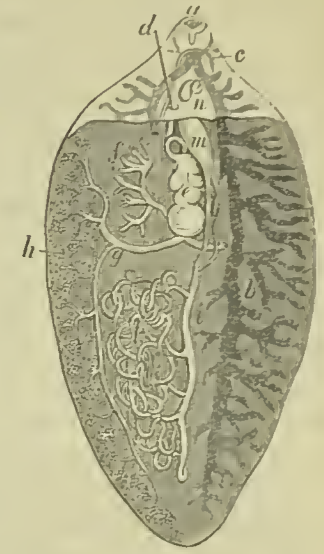
* Kuhn, Ann. Sc. Nat. 1 sér. xxix. p. 273; Siebold, Wiegmann's Archiv, 1845, and Siebold and Kölliker's Zeitschr. iv.; Gluge, Ann. Sc. Nat. 2 sér. viii. p. 314; Owen, Hunterian Lectures, i. p. 46; Dujardin, Helminthes, p. 635; Huxley, Ann. Nat. Hist. 2 ser. xiv. p. 379.

(371.) Through the walls of the ventral surface of the body two nervous filaments (*c*) are discoverable, which, crossing over the root of the anterior sucker or acetabulum, and gradually diverging, may be observed to run in a serpentine course towards the caudal extremity, where they are lost: it would even seem that on either side of the œsophagus there is a very slight ganglion, from which other nervous filaments arise to supply the suckers and the anterior part of the body.

(372.) The organs of generation in the fluke are very voluminous, occupying, with the ramifications of the alimentary tubes, the whole of the interior of the animal: in the diagram they are not represented on the right side, in order that the distribution of the intestine may be better seen; and on the left side the alimentary vessels are omitted, to allow the general arrangement of the sexual system to be more clearly intelligible.

(373.) These animals are completely hermaphrodite, not only possessing distinct ovigerous and seminiferous canals, which open separately at the surface of the body, but even provided with external organs of impregnation, so that most probably the cooperation of two individuals is requisite for mutual fecundity.

Fig. 71.



Anatomy f *Distoma*. *a*, anterior sucker and oral orifice; *b*, alimentary canal; *c*, nervous system; *d*, external opening of female generative apparatus; *e*, uterine receptacle: *f*, accessory appendage to ditto; *g*, oviduct: *h*, ovary; *i*, common canal, receiving *k*, convolutions of testis; *l*, vas deferens; *m*, capsule of the penis; *n*, intromittent organ.

(374.) To commence with the female generative system, we find the ovaria (*h*) occupying the whole circumference of the body. When distended with ova, the ovigerous organ is of a yellow colour; and when attentively examined under the microscope, it is seen to be made up of delicate branches of vesicles united by minute filaments, so as to have a racemose appearance. From these clusters of ova arise the ovigerous canals, which, uniting on each side of the body into two principal trunks, discharge their contents into the large oviducts (*g*). The oviducts terminate in a capacious receptacle (*e*), usually called the uterus: and from this a slender and convoluted tube leads to the external orifice, into which a hair (*d*) has been inserted. On each side of the uterus we find a large ramified organ, made up of cæcal tubes (*f*), which opens into the uterine cavity, and no doubt furnishes some accessory secretion needful for the completion of the ova.

(375.) The male apparatus occupies the centre of the body. The testes (*k*), in which the spermatic fluid is secreted, consist of convoluted vessels of small calibre, arranged in close circular folds, and so inextricably involved, that it is difficult to get a clear idea of their arrangement; but towards the middle of the median line they become more parallel, and terminate in two larger trunks (*i*) (one of which has been removed in the figure), which are enclosed and hidden in the seminal vessels. These great canals, which run side by side in a longitudinal direction, become gradually much attenuated (*l*), and terminate in the root or capsule of the penis (*m*). The external male organ (*n*) is placed a little anterior to the orifice which leads to the female parts: it is a short spiral filament, distinctly traversed by a canal, and perforate at the extremity, so as indubitably to perform the office of an instrument of intromission.

(376.) Among the most interesting discoveries of modern times is the establishment of the long-suspected fact that the Trematode Entozoa undergo certain metamorphoses during their development, and those of a most extraordinary and unheard-of character, exhibiting remarkable examples of the phenomenon of alternate generation. It is to the Danish naturalist, Steenstrup*, that science is indebted for the following account of his researches.

(377.) Although the best-known species of the numerous family of the Trematoda is the *fluke*, or *liver-worm*, of which the anatomical details are given above, similar forms are met with in almost all animals of the four higher classes; and among the lower, the Mollusca are equally infested by them.

(378). It might almost be said that in these classes every species is infested by its own fluke; in various animals, moreover, several different species of these parasites have been found, which inhabit either all the organs of the body indiscriminately, or are exclusively confined to one (liver, kidney, bladder), or to a definite part of an organ. Several of these Trematoda, as will be evident hereafter, when young, are not connected with any viscus, but enjoy the power of free locomotion in water, externally to the animal which, in their future state as Entozoa, they infest. In their free condition they are provided with a locomotive apparatus, usually a tail of moderate length, by the waving movement of which the creature propels itself through the water, like a tadpole, to which, in its external form, it is not dissimilar, though almost of microscopic dimensions. In this larval state the Trematode worms have long been known to naturalists under the generic name of *Cercaria*; but although it was well established that this form was not a permanent one, it was not until the researches of Nitzsch, Siebold, and Steenstrup revealed the true nature of the changes through which they pass, that we arrived at any satisfactory knowledge of their remarkable history.

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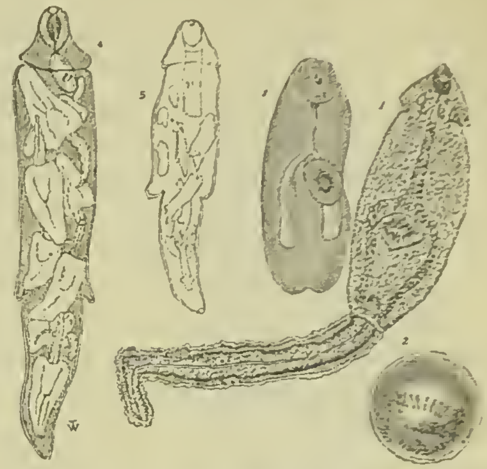
* Ueber den Generationswechsel in den Niederen Thierklassen, translated by the late Mr. Henfrey, in the publications of the Ray Society, 1842.

(379.) A *Cercaria*, supposed by Steenstrup to be the *Cercaria echinata* of Siebold (fig. 72, 1), is found by thousands in the water wherein specimens of the large fresh-water snails, *Planorbis cornea* and *Limnæus stagnalis*, have been kept. The body of this species of *Cercaria* is usually of a more or less elongated-oval form, which, however, it is constantly changing, assuming, during its movements, every outline, from the circular figure which it has in the fully contracted state, to the linear form that it presents when its body is fully extended; it is furnished, moreover, with a triangular head, at the apex of which is situated the oral orifice, surrounded with an apparatus of spinous teeth; and a ventral sucker is visible, situated upon the inferior surface of its body; while internally traces of viscera are discernible (as represented in the figure), the nature of which is not clearly made out.

Fig. 72.



1. *Cercaria echinata*? of Siebold. 2. Distoma-pupa, or Cercaria in the pupa state after it has cast off its tail and enclosed itself in a mucoid case. 3. The animal proceeding from the pupa a true Distoma, which has penetrated for a short distance into the body of the snail. 4. A "*nurse*" containing fully-developed Cercariæ: *v*, the stomach. 5. A "*parent-nurse*" filled with partially-developed "*nurses*:" *v*, the stomach. (After Steenstrup.)

(380.) The swimming movement of these Cercariæ is very characteristic: in performing it, the animal curves its body together into a ball, by which the head is brought near to the caudal extremity, and at the same time the elongated tail strikes out right and left into various sigmoid flexures. In this way they may be seen swarming about the water-snails in great numbers. After swimming about the snails for some time, they affix themselves, by means of their suckers, to the slimy integument of those animals, and all their movements upon it are readily perceived with a good glass. On examining, with a sufficient magnifying power, a portion of the skin of the snail with several of the Cercariæ adhering to it, it will be seen that all the efforts of these creatures are directed to the inserting of themselves deeper into the mucous integument, and to the getting rid of the tail, which is no longer of any use to them as an organ of locomotion; in this, after violent efforts, the Cercaria at length succeeds, and the now tailless animal assumes so completely the appearance of a Distoma or fluke, that it could not fail of being recognized as belonging to that genus, in case it were met with in this condition in the viscera of other animals. However, it undergoes a further remarkable transformation before it becomes a true Entozoon in the common acceptation of the word.

(381.) In various Cercariæ, a copious mucous secretion is observable on the surface of the body even before the loss of the tail, and this secretion apparently increases during the efforts of the animal to cast off this appendage. As soon as the tail has been got rid of, the Cercaria begins, by extending and contracting its body, to turn itself round and round in the same spot. By this sort of movement it makes for itself a circular cavity within the mucus, which gradually hardens, and forms a tough, nearly transparent case around it. This is the noted *pupa*-state of the Cercariæ, observed first by Nitzsch*, and afterwards by Siebold. The tailless Cercariæ remain concealed under their transparent case, which is arched over them like a small, closely-shut watch-glass (fig. 72, 2). In this condition they remain some months in a quiescent and inactive state, when they present themselves with all the characters of real *Flukes* (fig. 72, 3), and may be found under this form lodged in the liver or appropriate viscera in the interior of the snail.

(382.) Having thus seen that the *Cercaria* becomes an actual *Fluke*, it next remains to inquire what is the origin of the Cercaria. The Fluke deposits ova, from which, either within the body of the parent, or external to it, oval-shaped young proceed, which move about briskly in the fluid contained in the interior of the snail or in the surrounding water, and bear no resemblance to their parent. In what way this progeny is transformed into a Fluke, or rather, as we now know, into a Cercaria, is as yet an unexplained mystery; but that this change can and does take place only by the intervention of *several generations* may be assumed as beyond doubt.

(383.) The free-swimming Cercariæ, afterwards converted into pupæ, as above described, have been proved, by the observations of Bojanus, to be produced from little worms of a bright yellow colour (fig. 72, 4) ("königsgelben Würmern"), described by him, and which occur in great numbers in the interior of snails, especially of *Limnæus stagnalis* and *Paludina vivipara*. It is consequently in these yellow worms, which are about 2 lines long, that the Cercariæ, which are the larvæ of the actual Flukes, are developed; and since we now know that the Flukes are perfect animals, which themselves undergo no transformation and are propagated by ova, we are reduced to the conclusion that the progeny is indebted for its origin and development to creatures which, in external form, and partly in internal organization, differ from the animals into which that progeny is afterwards developed; in other words, it may be said that we here meet with a generation of *nurses*, and that the yellow cylindrical worms of Bojanus, which inhabit the snail, are the *nurses* of the Cercariæ and Distomata†.

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* Beitrag zur Infusorienkunde, oder Naturbeschreibung der Zercarien und Bacillarien. Halle, 1817.

† That the *Cercariæ* are actually developed in the above-mentioned yellow worms, any one may be easily convinced who will take a dozen large specimens of *Limnæus*

(384.) The "nurses" usually present the appearance of the figure given above (fig. 72, 4). The body is cylindrical, and is furnished in most instances with a spherical contracted head, which includes an oral cavity with very muscular walls and a small circular mouth. At some distance posterior to the middle of the body are situated the two characteristic oblique processes, which, as well as the part of the trunk posterior to them, are simply local dilatations of the cavity of the body. Of internal organs, there is only to be seen an undivided sacculated stomach (v), very small in proportion to the size of the animal.

The whole remainder of the very large body is filled with the brood of *Cercariæ*. In the instance figured above (fig. 72, 4), all the embryos have simultaneously reached their full development, which is but seldom the case, since, in the same individual, *Cercariæ* are found in all stages of development.

(385.) Some doubt exists as to the mode in which the *Cercariæ* quit their "*nurses,*" since it has been observed, under the microscope, that there are two places where they come away, viz. from each side of the body, at a depression under the collar, and from the abdominal surface, between the two oblique processes: but they escape from the latter situation only when the animal has been slightly compressed between the glasses; and from the former, on the contrary, when no pressure at all has been employed.

(386.) It next remains to trace the origin of the "*nurses*" themselves. Siebold (who did not regard these as independent animals, but only as living organs of generation, "*germ-sacs*") expresses his surprise at seeing them developed from germs which are always contained in other creatures having the same outward appearance as themselves; and Steenstrup saw, with like astonishment, that it constantly occurred, in some of the snails taken from the same places as the others, that they harboured only Entozoa which had the outward form of the "*nurses,*" but which, instead of Cercariæ, contained a progeny consisting of actual "*nurses*" in all stages of development. This was the case only in some, and those rather young snails, whilst all the others were inhabited by "*nurses*" whose progeny were true *Cercariæ*; it cannot, therefore, be doubted that it is normal for the "*nurses*" to originate in creatures of similar appearance to themselves, and which are thus the "*nurses*" of "*nurses.*" These "*parent-nurses,*" however (fig. 72, 5), notwithstanding their great resemblance, were not difficult to be distinguished from the common ones; the stomach, for instance, in the full-

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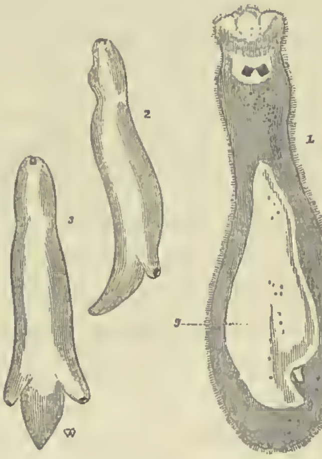
stagnalis from small stagnant pools that have been exposed to the sun; the worms will be very readily found. They are situated not so much in the viscera themselves (the liver and reproductive organs) as in the membranes covering them, and their long bodies will be found half-floating as it were in the fluid which occupies the space between the organs, and which appears to be pure water entering through the water-canals.

grown "parent-nurses" is longer and wider than in any even of the youngest "nurses." (Compare fig. 72, 4, with fig. 72, 5.)

(387.) We have thus followed the *Distoma* to its third stage of ascent, and, as no more stages in the generations of these animals have been detected, are not in a condition to trace the origin of the *Distoma* further back. Steenstrup, however, entertains the not unfounded supposition that the "parent-nurses" are not produced from other similar creatures, but that *they* proceed originally from ova derived from the full-grown Fluke,—a supposition which derives additional importance from observations made upon the development of other Entozoa belonging to the Trematode group.

Fig. 73.



1. First stage in the development of *Monostomum mutabile*, after it has quitted the egg and is swimming about at liberty: *g*, internal embryo of "*parent-nurse.*" 2, 3. The same, after its metamorphosis from an active form into an inactive sluggish creature, which is not itself a mother, but which nourishes within it a progeny from which, in the third generation, a parent animal proceeds. (After Siebold.)

(388.) In *Monostomum mutabile**, for example, which inhabits several of the cranial cavities lined with mucous membrane in certain water-birds, the young embryo is frequently hatched before or just as the ovum is expelled. The newly-hatched young (fig. 73, 1) are elongate-oval, and furnished at their anterior extremity with some short lobes, which the animal is able to protrude and retract; and its whole surface is covered with vibratile cilia, by the aid of which it moves readily in the water. In the anterior part of the body are two quadrangular spots, which can scarcely be regarded as anything but eyes. The posterior two-thirds of the trunk are occupied by a slightly transparent whitish body (*g*), which it might be supposed was one of the viscera, as Siebold thought it to be, if it were not that after a time, and some rather vigorous motions, it becomes detached, ruptures the body of its parent, and presents itself as an animal of entirely different appearance from that in which it lay concealed and was developed (fig. 73, 2, 3).

(389.) Now, since this enclosed animalcule is constantly present in the ciliated young *Monostomum*, and as there is *always but one* animalcule in each individual, and always in the *same situation*, there must necessarily be some organic connexion between the two, and one entirely different from that which it has been supposed could be explained by styling the one a necessary parasite of the other. If one animal is, organically speaking, necessarily connected with another, so that each can be developed only in or around the other, they must belong to one and the same unity, or constitute such a unity; and this is doubtless the case with the animals we are now considering.

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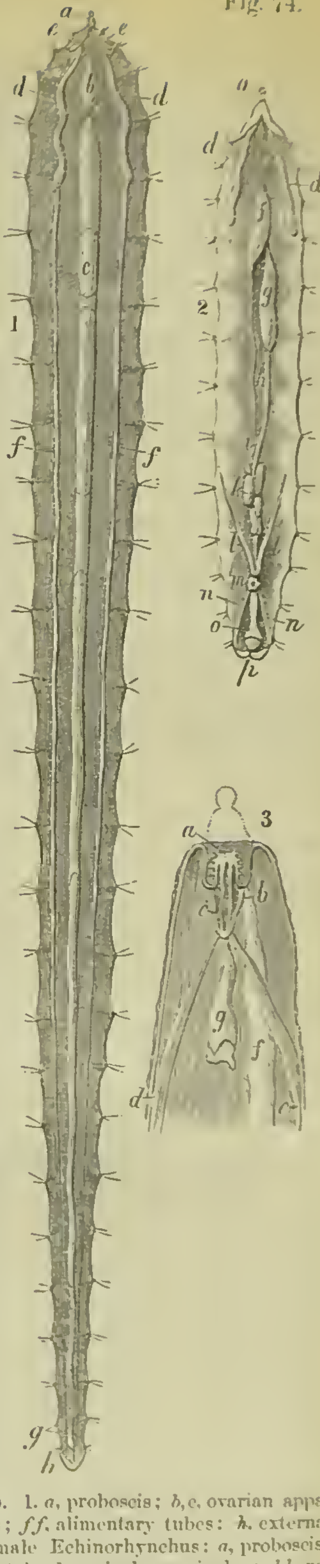
* *Vide* Wiegmann's Archiv für Naturgeschichte, 1836.

(390.) The ACANTHOCEPHALA*, called likewise ECHINORHYNCHI, constitute a distinct group of Helminthozoa, distinguished by the remarkable armature of their oral apparatus, as well as by the peculiarities of their internal organization.

(391.) The *Echinorhynchi* inhabit the intestinal canal of various animals, to the walls of which they fasten themselves by a singular contrivance. In the *Echinorhynchus gigas*, which is found in the intestines of the hog, the head (*a*, fig. 74, 1, 2, 3) is represented by a retractile proboscis, armed externally with four circlets of sharp recurved hooks, which, when plunged into the coats of the intestine, serve as secure anchors whereby the creature retains itself in a position favourable to the absorption of food. In fig. 74, 1, 2, this aculeated proboscis is represented of its natural size, relative to the body of the Entozoon, as it appears when fully protruded; but when not in use, the spinous part is retracted, and concealed by the mechanism of which an enlarged view is given at fig. 74, 3. When extended, the position of the organ is indicated by the dotted lines; but in the drawing the whole organ is represented as drawn inwards and lodged in a depression formed by the inversion of the integument, so as to completely to hide it within the body. This inversion is produced by the contraction of two muscular bands, *d*, *e*, which arise from the inner walls of the body, and are inserted into the root of the pro-

Fig. 74.



Anatomy of *Echinorhynchus gigas*, female (after Cloquet). 1. *a*, proboscis; *b*, *c*, ovarian apparatus; *d d*, lemnisci; *e e*, retractor muscles of the proboscis; *f f*, alimentary tubes: *h*. external opening of the female generative system. 2. Anatomy of male Echinorhynchus: *a*, proboscis; *d*, lemnisci; *f*, *g*, testes; *h*, vasa deferentia. uniting together at *i*: *k*. vesiculæ seminales; *l l*, retractor, and *n n*, protruding muscles of the penis; *m*. their point of insertion into *o*, the penis; *p*, generative aperture. 3. Mechanism of the proboscis: *a*, its extremity covered with curved spines; *b*, *c*, its protractile sheath; *d*, *e*, retractor muscles; *f*, lemniscus; *g*, ovary.

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* Cloquet, Anatomie des Vers intestinaux. Paris, 1824.

boscis around the œsophagus*; two other muscles, *b b*, antagonistic to the former, arise near the spines themselves; and these, aided by the contractions of the walls of the body, are the agents by which the protrusion of the head is effected. Although the teeth or spines which render this organ so formidable are merely epidermic appendages, they are raised or depressed at the will of the creature; and it is therefore probable that, minute as they are, they have muscular fibres connected with them, serving for their independent motions. These spines, moreover, are not always confined to the head, but in many acanthocephalic worms are found on various parts of the body, wherever their office as instruments of attachment is by circumstances rendered needful.

(392.) The digestive system of the Echinorhynchus is extremely simple. The mouth is a minute pore, placed at the extremity of the proboscis, which communicates with two slender canals, *f f*, at first of great tenuity, but near the middle of the body assuming something of a sacculated appearance. Towards the tail these vessels gradually diminish in size, until they are no longer distinguishable; but they have not been seen to give off any branches, or to communicate with each other.

(393.) Near the origin of these nutrient tubes are two large cæca, nearly an inch in length, called *lemnisci* (fig. 74, 1 & 2, *d d*), which are probably connected with the digestive function.

(394.) The female Echinorhynchus, as is usually the case in Diœcious Entozoa, is considerably larger than the male, as may be seen in the figure. In the former (fig. 74, 1), the ovary, *c*, is a capacious organ, occupying the centre of the body, and extending along its entire length. When minutely examined, it is found to consist of two compartments, or distinct sacs, one occupying the dorsal, the other the ventral aspect—the two tubes being separated by a septum. The dorsal ovary commences near the tail, at *g*, by a *cul-de-sac*, and, enlarging as it runs forwards, terminates near the point, *c*, by uniting with the ventral portion. The anterior part of the canal, *b*, is common to both divisions of the ovary; and from this the ventral tube runs backwards to the posterior end of the body, where it terminates in a narrow duct, which opens externally at *h*. It would seem, therefore, that the last-mentioned opening is the only excretory passage from the ovarium,—the connexion apparent in the figure, between the common sac, *b*, and the root of the proboscis, being merely of a ligamentous character.

(395.) In the female of some of the Acanthocephali, according to Siebold†, there are neither proper ovaries nor a uterus, but in their place are found numerous oval or round flattened bodies of considerable size, which float freely in the anterior of the cavity of the body; they have regularly-defined borders, and are composed of a vesicular, granular substance; in these the eggs seem to be formed, so that they may

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[*] These muscles are seen of their natural size in fig. 74, 1, at *c c*.

[†] Siebold and Stannius, Comp. Anat. p. 121.

be regarded as so many loose ovaries. When the eggs have reached a certain size, they fall from the ovaries into the cavity of the body, where they continue to increase in size, and become enclosed in additional envelopes. When mature, the ova escape through a muscular canal, which terminates immediately at the vulva, the latter being a simple aperture, situated at the posterior extremity of the worm. The muscular canal, through which the eggs escape, is of a campanulate or infundibuliform shape, opening internally by an aperture whose borders float freely in the cavity; of the body and thus the whole apparatus might be compared to a Fallopian tube.

(396.) The generative system of the male Echinorhynchus is represented in fig. 74, 2. The organs which secrete the fecundating fluid are two cylindrical vesicles (*f*, *g*), attached at one extremity by minute filaments to the walls of the body; from each of these arises a duct (*h*), and the two, uniting at *i*, form a common excretory canal. This canal speedily dilates into a number of sacculated receptacles, in which the secretion of the testes accumulates; and from them a duct leads to the root of the penis (*m*). The penis or organ of copulation, when extended, protrudes through the aperture (*p*) placed at the anal extremity of the body; but when retracted, it is folded up and lodged in a conical sheath (*o*). The protrusion and retraction of this part of the male apparatus is effected by a very simple mechanism: two muscles (*l l*), arising from the inner walls of the body, are inserted into the base of the sheath (*m*), and serve to draw it inwards; and two others (*n n*), inserted at the same point, but arising from the posterior extremity of the animal, by their contraction force outwards the copulatory organ—an arrangement precisely corresponding with that by which the movements of the proboscis are provided for.

(397.) The TURBELLARIÆ, constituting another important group of the Helminthozoa, are mainly characterized by having the exterior of their bodies densely covered with vibratile cilia, by the agency of which they swim freely about. They are not parasitical in their habits, and are met with under various forms, both in the sea and in fresh water. They may be divided into two families, the PLANARIÆ and the NEMERTIAN WORMS.

(398.) The PLANARIÆ, although they do not inhabit the interior of other animals, are nearly allied in every part of their organization with the Flukes (*Distoma*); so that their history cannot be more appropriately given than in this place. The Planariæ are common in ponds and other stagnant waters; they are generally found creeping upon the stems of plants, or amongst the healthy confervæ which abound in such situations, and wage perpetual war with a variety of animals inhabiting the same localities. The body of one of these minute creatures appears to be entirely gelatinous, without any trace of muscular fibre *: yet its motions are exceedingly active, and it glides along the plane upon which it moves with a rapid and equable pace—of which the observer would scarcely expect so simple a being to be capable,—or, by means of two terminal suckers, progresses in the manner of a leech.

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* Dugès, Ann. des Sc. Nat. 1828.

(399.) Many of the larger marine species are able to swim freely in the sea by the aid of violent flappings of the broad margins of their bodies, whereby they beat the water much in the same way as the broad fins of a skate—movements which it would be difficult to explain, except by admitting the existence of a subcutaneous plane of muscular fibres, such as is described by M. de Quatrefages as being recognizable in some species.

(400.) Although the existence of a nervous system in the Planariæ has been doubted by some observers, the researches of M. de Quatrefages assure us of its presence in many species. It consists of two ganglions, more or less intimately united, which are situated in the mesial line near the anterior part of the body. This double ganglion, which may be called the brain, and which is sometimes visible to the naked eye, is lodged in a special lacuna or cavity, recognizable from its transparent outline, and is seen to give off nervous filaments in various directions to different parts of the body.

(401.) M. Blanchard*, in dissecting a large individual belonging to this group, not only found the two cerebroid nervous centres, above alluded to, closely approximated, but observed that they gave origin to two long cords, which exhibited at regular intervals a series of minute ganglia, thus clearly approximating to the type of structure that characterizes the lower forms of the annulose worms.

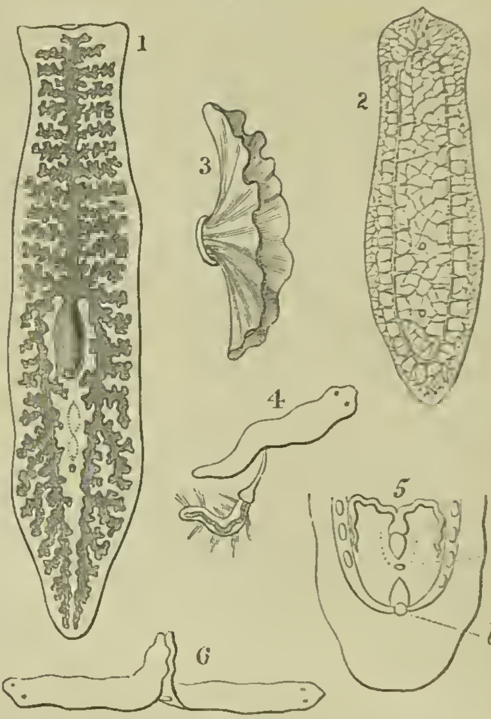
(402.) Many species of Planariæ possess two red specks upon the anterior part of the body, which, as in other cases, have been unhesitatingly pronounced to be eyes, although their claim to such an appellation is not only unsubstantiated by any proofs derivable from their structure, but completely negatived by experiments, which go to prove that, in the pursuit of prey, no power of detecting the proximity of their food, by the exercise of sight, is possessed by any of them.

(403.) The phenomena which have been observed, connected with the multiplication of the Planariæ by division, are analogous to those which we have witnessed in other acrite animals; for it has been proved that, if an individual be cut to pieces, every portion continues to live and feel, from whatever part of the body it may be taken; and, what is not a little remarkable, each piece, even if it be the end of the tail, as soon as the first moment of pain and irritation has passed, begins to move in the same direction as that in which the entire animal was advancing, as if the body was actuated throughout by the same impulse; and, moreover, every division, even if it is not more than the eighth or tenth part of the creature, will become complete and perfect in all its organs.

* Sur l'Organisation des Vers, Ann. des Sc. Nat. 1847.

(404.) The mouth, in a few species of Planariæ, is placed at the anterior extremity of the body, but generally it is found to occupy the middle part of the ventral surface. Its structure is quite peculiar, and admirably adapted to the exigences of the creature: it consists of a wide, trumpet-shaped proboscis (fig. 75, 3 & 4), which can be protruded at pleasure, and applied to the surface of such larvæ or red-blooded worms as may come within reach, so as to suck from them the juices which they contain; or if the prey be small, such as animalcules and minute crustacea, they are seized by it and conveyed into the digestive canals. The internal organs appropriated to nutrition resemble in all essential points those of the Distoma; they consist of a multitude of blind tubes, ramifying in the parenchyma of the body, which, when distended with coloured substances, are sufficiently distinct. The principal trunk (fig. 75, 1), which communicates with the proboscidiform mouth, soon divides into three primary branches, one of which runs along the median line towards the anterior extremity, whilst the other two are directed backwards towards the tail. From these central canals secondary ones are given off, which permeate all parts of the creature. There is no anal aperture; so that, of course, the residue of digestion is expelled through the mouth; but the nature of the process by which defecation is thus effected is curious: the Planaria, slightly bending itself, is seen to pump up through its proboscis a quantity of water, with which all the branches of the alimentary ramifications are filled; the creature then contracts, and, forcibly ejecting the contained fluid, expels with it all effete or useless matter.

Fig. 75.



Structure of *Planaria* (after Dugès). 1. Ramifications of alimentary canal. 2. Vascular system. 3. Proboscis unfolded. 4. Represents a Planaria devouring a Nais, showing the action of the proboscis. 5. Generative system: *a*, male apparatus; *b*, female ditto. 6. Two Planariæ in the act of copulation.

(405.) In the larger marine species, M. de Quatrefages* recognizes the existence of an internal general or visceral cavity, which he invariably found filled with a transparent fluid kept in continual agitation by the various movements of the animal. The flux and reflux of this fluid are rendered conspicuous by the movements hither and thither of numerous round diaphanous corpuscles which enter as morphotic elements into its composition and render indisputable its identity of character with the chylaqueous fluid of the more highly organized worms, in which the internal viscera are freely suspended, their parietes being merely kept *in situ* by delicate membranous frena.

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* Ann. des Sc. Nat. 1845.

(406.) Besides the arborescent tubes in which digestion is accomplished, a rudimentary vascular system is distinctly visible, whereby the nutritive juices are dispersed through the system. This consists of a delicate network of vessels, arising from three large trunks, one placed in the centre of the dorsal aspect, and the other two running along the sides of the animal (fig. 75, 2).

(407.) The Planariæ are perfectly androgynous, as each individual possesses a distinct male and female generative system; but they are not, apparently, self-impregnating, seeing that the cooperation of two individuals has been found needful for the mutual fertilization of their ova. In every one of these animals two distinct apertures exist upon the ventral surface, at a little distance behind the root of the proboscis, the anterior of which gives issue to the male organ, while the posterior leads to the ovigerous or female parts.

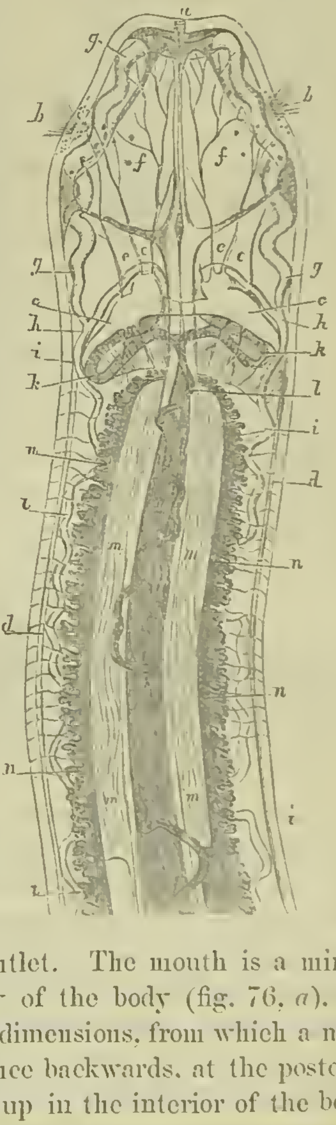
(408.) In *Planaria tremellaris*, the penis, which during copulation is protruded from the anterior orifice (fig. 75, 6), is a white contractile body, enclosed, when in a retracted state, in a small oval pouch; it is perforated with a minute canal, and receives near its root two flexuous tubes, which gradually decrease in size as they diverge from each other, until they can no longer be traced. These are the seminiferous vessels (fig. 75, 5, *a*). The posterior genital orifice, which leads to the female organs, communicates with a small pouch, or uterus, as it might be termed (fig. 75, 5, *b*); into this open two lateral oviducts, which run on each side of the male apparatus and of the proboscis; these are very transparent, and only recognizable under certain circumstances by the ova which they contain. In *Planaria lactea* the oviduct opens into the uterine cavity by a single tube, which, passing backwards, divides into two equal branches; and both of these, again subdividing, ramify extensively among the cæca derived from the stomach. We likewise find in this species two accessory vesicles, which pour their secretions into the terminal sac.

(409.) The Nemertean Helminthozoa are marine animals, frequently found lurking beneath stones, or in clefts of rock, on shores left by the retreating tide. In their external appearance they have some resemblance to Tæniæ, and, like them, are occasionally met with of prodigious length. In their anatomical structure, however, they differ widely from the Tape-worms, as will be immediately evident from the following details.

(410.) The body is covered with a sort of semifluid varnish, the whole surface of which is densely clothed with extremely delicate and closely set vibratile cilia, so minute as to be perceived with difficulty, except in the vicinity of the head, where, at certain points, they present more conspicuous dimensions (fig. 76, *b b*).

(411.) The alimentary apparatus presents a remarkable uniformity of arrangement, and, for the purpose of description, may be divided into the mouth, the proboscis, the œsophagus, and the intestine. There do not appear to be either salivary or hepatic glands; neither is the intestinal canal provided with an anal outlet. The mouth is a minute orifice, situate at the anterior extremity of the body (fig. 76, *a*), and generally surrounded with cilia of large dimensions, from which a muscular canal is prolonged for some distance backwards, at the posterior extremity of which may be seen, folded up in the interior of the body, a powerful proboscis, which is protrusible at the will of the animal, and.

Fig. 76.



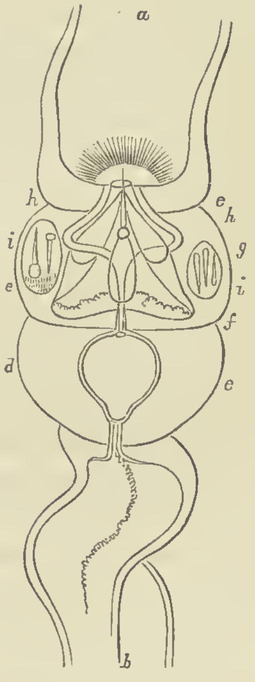
Anterior portion of *Borlasia camillea*. *a*, buccal orifice; *b b*, cephalic fossa, provided with vibratile cilia; *c c*, lobes of the brain, brought into communication with each other by means of a broad sub-œsophageal commissure, and apparently composed of several ganglia conjoined; *d d*, longitudinal nervous trunks, whence branches are derived which supply the muscles and internal viscera; *e e e e*, cephalic nerves; *f f*, groups of eye-like specks; *g g*, cephalic loop of the vascular system; *l l*, medio-dorsal vessel, which, on entering the cephalic cavity, bifurcates to form the trunks, *k k*, that encircle the brain, and afterwards, at *h h*, become continuous with the lateral vessels, *i i*; *m m m m*, horizontal diaphragm, forming a sheath, in which is lodged the anterior portion of the proboscis, *o o*; *n n*, the ovaria (testes in the male), furnished with cæca that float freely in the lateral chambers of the body. The space comprised between the septa, to which the generative organs are attached, forms the central longitudinal cavity wherein is lodged the digestive apparatus.

like that of the Planaria described above, is a most efficient instrument for seizing prey. Immediately behind the proboscis is situated a very remarkable apparatus in the shape of an extremely muscular œsophagus, wherein is lodged a weapon of most extraordinary character, consisting of a solid transparent spiculum, lodged in a cavity, formed in the thickness of the œsophageal parietes, wherein is contained a glandular mass, by which the calcareous spiculum is apparently secreted (fig. 77, *g*). Other glandular structures (*h h*), probably destined for the elimination of some venomous secretion, are in communication with the styliferous cavity; so that the dagger-like spiculum, being constantly bathed with the secretion thus furnished, becomes an instrument of a very deadly character. The dagger-like weapon, together with its immediate appendages, is capable of being protruded by the aid of muscular bands in connexion with the styliferous cavity, which at the same time, by compressing the glands, readily cause the emission of their secretion. On each side of the formidable apparatus above described, there are, moreover, two other cavities, apparently of an auxiliary character (fig. 77, *i i*), in which a secretion of supernumerary spicula is perpetually in progress, apparently destined to replace the original one if lost or broken.

(412.) The intestine (fig. 77, *b*), properly so called, succeeds immediately to this strangely organized œsophagus, and is continued backwards, floating in the central compartment of the body, to which it is loosely attached by membranous bridles for about three-fourths of the length of the worm, at which point its calibre rapidly diminishes and its cavity soon becomes obliterated, so that it terminates under the aspect of a simple cord.

(413.) The Nemertean Helminthozoa are possessed of a very complete circulatory system of vessels enclosed in proper walls. These consist of three principal trunks, two of which run along the sides of the ventral aspect of the body (fig. 76, *i i*), while the third occupies the middle of the dorsal surface (fig. 76, *l l*): these three vessels become considerably increased in size as they approach the posterior extremity of the worm, and ultimately are conjoined.

Fig. 77.



Styliferous apparatus of *Polia mandilla*: *a*, portion of proboscis; *b*, portion of the intestine; *c*, first œsophageal dilatation; *d*, second œsophageal dilatation; *e e*, œsophageal canal, presenting sundry dilatations and contractions; *f*, cavity in which is lodged the spiculum, *g*; *h h*, poison?-glands in connexion with the spiculum, *g*; *i i*, cavities enclosing incompletely formed spicula.

(414.) The median vascular trunk, throughout the greater part of its course, is situate immediately beneath the subcutaneous muscular layers;

but when it arrives at the sheath of the proboscis it becomes enclosed in a special canal, and thus penetrates into the cephalic region, where it bifurcates to form the two lateral trunks, *k k*, which, after forming almost a complete circle around the cerebral ganglia, anastomose with the lateral vessels, *i i*.

(415.) The vessels of the body thus becoming conjoined at the points *h h*, form a loop, *g g*, which surrounds the cephalic region, and is of considerably greater calibre than the trunks from which it is derived.

(416.) The fluid contained in the vascular system above described is generally colourless, but sometimes of a reddish or yellowish tinge; it is, however, completely devoid of blood-corpuscles, resembling, in this respect, the blood of the Annelidans, which will be described on a future occasion.

(417.) In these worms, the central or abdominal space is separated from the two lateral cavities by vertical septa, to which the reproductive organs are attached. The latter consist of a series of cæca (fig. 76, *n n*), which are so exactly alike in the two sexes, that it is impossible to distinguish the male from the female, except by their contents. These cæca are apparently formed of several layers of cells, and are covered externally with vibratile cilia. Except during the period of reproduction, they contain, in both sexes, nothing but an opaline fluid; but when called into action, the ovaria in the female are found to be filled with a liquid wherein corpuscles of various shapes are seen to be suspended. Some of these have the appearance of perfectly diaphanous spheres, which are sometimes isolated, at others surrounded with granulations; and likewise oil-drops of a beautiful golden colour may be detected: but the ovaria never seem to contain perfectly developed ova; these are only met with in the lateral cavities of the body, where they may frequently be seen, in different stages of development, floating about between the cæca. The vitellus and Purkinjean vesicle are always more or less apparent. When these eggs have acquired their full growth, they stuff, so to speak, the whole body of the worm, pressing upon the alimentary canal to such a degree that it seems in danger of becoming atrophied, and almost completely effacing the median abdominal cavity; nay, so closely are they squeezed against each other, that they lose their spherical form and become polygonal. The number of these eggs is prodigious; and M. de Quatrefages estimates seven or eight thousand to be a moderate complement for a middle-sized worm of this description.

(418.) The male Nemerteans present phenomena very similar to those just described as occurring in the female. At the period of reproduction, the testicular cæca become filled with granulations of various sizes, sometimes isolated, sometimes grouped together in round masses; but these do not contain spermatozoids. The latter seem only to occur in the lateral cavities of the body; and even there they are found in various stages of development, from granular masses, such as are met with in the ovaria, to aggregations of spermatozoids provided with tails and subsequently isolated. At length the body of the male Nemertean appears to be as completely stuffed with spermatozoids as that of the female is with eggs, and they are ultimately expelled, in prodigious numbers, into the surrounding water.

(419.) The Cœlelmintha, or cavitary intestinal worms of Cuvier, evidently present a much higher type of structure than any of the preceding. The *Ascaris lumbricoides*, as its name imports, so strongly resembles some of the Annelida in its external configuration, that the zoologist who should confine his attention to outward form alone, might be tempted to imagine the affinities connecting them much stronger than a comparison of their anatomical relations would sanction. This Entozoon is found in the intestines of many animals, and is endowed with some considerable capability of locomotion, adapted to the circumstances under which it lives; for in this case the worm, instead of being closely imprisoned in a circumscribed space, may traverse the entire length of the intestines in search of a convenient locality and suitable food.

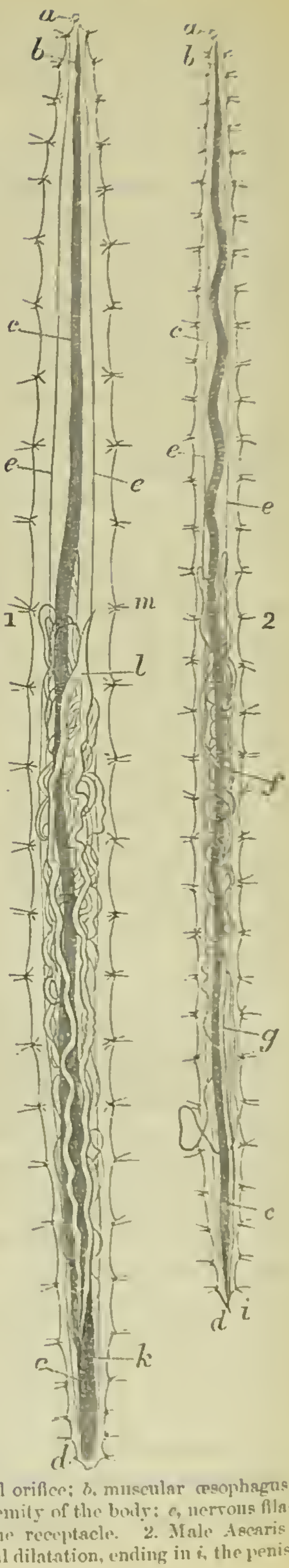
(420.) In accordance with such an enlarged sphere of existence, we observe muscular fibre distinctly recognizable in the tissues that compose the walls of the body—not as yet, indeed, exhibiting the complete characteristics of muscle as it is found in higher animals, but arranged in bundles of contractile filaments, running in determined directions, and thus capable of acting with greater energy and effect in producing a variety of movements.

(421.) In this rudimentary state, the muscular fibre does not possess the density and firmness which it acquires when completely developed; it has, when seen under the microscope, a soft, gelatinous appearance, apparently resulting from a deficiency of fibrin in its composition; the transverse striæ, usually regarded as characteristic of the muscular tissue of the more perfect animals, are not yet distinguishable; and the individual threads are short, passing over a very small space before they terminate. On examining the arrangement of these fasciculi, they are seen to be disposed in two layers, in each of which they assume a different course; thus, in the outer layer they are principally arranged in a longitudinal direction, while the inner stratum of fibres is placed transversely, affecting a spiral course, so as to encircle the viscera. From this simple structure various movements result: by the action of the longitudinal fasciculi the whole body is shortened; by the contractions of the spiral layer an opposite effect is produced; or by the exertion of circumscribed portions of the muscular integument, lateral flexions of the body are effected in any given direction. These motions in the living worm are vigorous, and easily excited by stimuli; they are therefore abundantly sufficient for the purpose of progression in such situations as those in which the creature lives, and enable it to change its place in the intestines with facility.

(422.) Around the mouth or anterior part of the œsophagus there appears to be a delicate nervous ring, probably specially connected with the association of such movements of the oral extremity as are essential to the imbibition of nourishment. From this oral ring proceed two long nervous filaments (fig. 78, *e e*), one of which runs backwards along the dorsal aspect of the body, while the other occupies a similar position upon the ventral surface. The last-named filament is described by Cloquet as dividing, in the female *Ascaris,* at the point where the termination of the organs of generation issues from the body (fig. 78, 1, *m*), so as to enclose the termination of the vagina in a nervous circle.

(423.) The digestive apparatus in this order of intestinal worms is very simple. In *Ascaris lumbricoides* the aperture of the mouth (fig. 78, *a*) is surrounded by three minute rounded tubercles; into each of these, fasciculi, derived from the longitudinal muscles of the body, are inserted in such a manner as to cause the separation of the tubercles and consequent opening of the mouth, which is again closed by a sphincter muscle provided for the purpose. To the mouth succeeds a short œsophagus (fig. 78, 1 & 2, *b*), which is separated by a constriction from the rest of the alimentary canal, and would seem, from the muscularity of its walls, to be an agent employed in sucking-in the liquid food upon which the creature lives. The true digestive cavity (fig. 78, 1 & 2, *c c*) is a simple and extremely delicate tube, which arises from the œsophagus, and, without presenting any appearance indicative of separation into stomach and intestine, gradually enlarges as it proceeds backwards, until it terminates at the hinder extremity of the body by a narrow aperture (fig. 78, 1 & 2, *d*).

Fig. 78.



Anatomy of *Ascaris lumbricoides.* 1. Female Ascaris: *a*, oral orifice; *b*, muscular œsophagus; *c*, alimentary canal; *d*, termination of ditto at the posterior extremity of the body; *e*, nervous filaments; *k*, convolutions of the two ovigerous canals; *l*, uterine receptacle. 2. Male Ascaris: *a*, *b*, *c*, *d*, *e*, as above; *f*, convolutions of the testes; *g*, its terminal dilatation, ending in *i*, the penis.

(424.) It would seem that the food of these Entozoa, being already animalized by having undergone a previous digestion, requires little further preparation; and we are not surprised at finding, in the generality of the *Cœlelmintha*, no accessory glandular apparatus appended to the digestive canal for the purpose of furnishing auxiliary secretions. In two species only have tributary secreting organs been detected. In one example, *Gnathostoma aculeatum* (Owen), found in the stomach of the tiger, and which is remarkable as possessing a pair of rudimentary jaws, four elongated cæca are appended to the mouth, into which they pour a fluid, analogous, no doubt, to that of the salivary glands*; in a species of *Ascaris*, found in the stomach of the dugong, Professor Owen likewise discovered a cæcal appendage opening into the alimentary tube, at some distance from the mouth, and which, without much stretch of imagination, might be regarded as the first and simplest rudiment of a biliary system†.

(425.) In further prosecuting our inquiries concerning the process of nutrition in these Entozoa, we must now speak of a peculiar structure, first noticed by Cloquet‡, and apparently intimately connected with the assimilation of nutriment. Projecting from the inner surface of the abdominal cavity, especially in the dorsal and ventral regions, there are a great number of gelatinous, spongy processes (*appendices nourriciers*), which, although they have no apparent central cavity, would seem to be appended to vascular canals seen upon the lateral aspects of the body: it is probable, therefore, that their office is to absorb the nutritive juices that exude through the delicate walls of the intestine and convey them into the circulatory apparatus; or they may be reservoirs for nourishment, analogous to the adipose tissue of higher animals.

(426.) In the *Cœlelmintha* the sexes are separate; and the generative organs, both of the male and female, exhibit great simplicity of structure. In the female *Ascaris*, the aperture communicating with the ovigerous apparatus is placed upon the ventral aspect of the body, a little anterior to the middle of the worm (fig. 78, 1, *m*). This opening leads to a wide canal (*l*), usually called the uterus; and from the last-mentioned organ arise two long and undulating tubes, which, diminishing in size, run towards the posterior extremity, where they become completely filiform, and, turning back upon themselves, are wound in innumerable tortuous convolutions around the posterior portion of the alimentary canal, until the termination of each becomes nearly imperceptible, from its extreme tenuity. In these tubes, which, when unravelled, are upwards of 4 feet in length, the ova aro formed in great numbers, and are found to advance in maturity as they approach the dilated terminal receptacle common to both oviducts (*l*), from which they are ultimately expelled.

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* Owen, Proceedings of the Zoological Society, Nov. 1836.

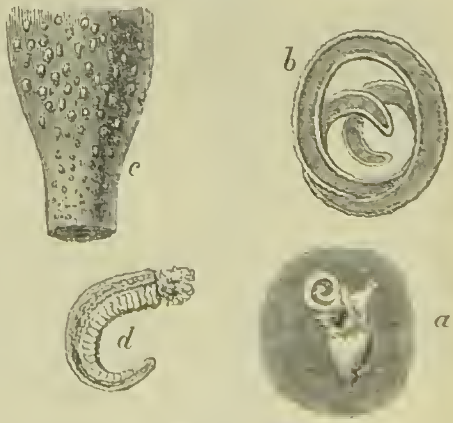
† Preparation No. 429 A, Mus. Coll. Surg., Phys. Catalogue, p. 121.

‡ Anatomie des Vers intestinaux. Paris, 1824.

(427.) The attenuated commencements of the genital tubes in the female *Ascaris* may be considered as representing the ovary, wherein may be discovered numerous small round cells, which, as they advance forward, begin to be surrounded with a granular vitelline substance, wherein the primitive nucleated cells are still visible: these cells, therefore, ought perhaps to be regarded as germinal vesicles. Still further onward the eggs are of a discoidal shape, and are arranged in a row, or are grouped closely around a rachis that traverses the axis of the ovary. In that portion of the genital canal which may be considered as representing the Fallopian tube the ova become more mature, and subsequently, surrounded by a double colourless envelope, pass into the base of the uterus. This last is the widest portion of the genital tubes, and is distinguished in the living animal by its well-marked peristaltic action. The vagina, distinguishable from the uterus by its narrowness and its muscular walls, opens into the vulva—a narrow transverse fissure, sometimes surrounded by a very remarkable fleshy swelling, generally situated either in front of or near the middle of the body, but in some cases in the vicinity of the anus. The sperm is usually accumulated in the bottom of the uterus to such an extent as to render it probable that this is the locality where the fecundation of the ova takes place *.

(428). The male *Ascaris lumbricoides* is considerably smaller than the female, and the structure of its generative system remarkably similar to what has been just described in the other sex. The testis or gland, which secretes the impregnating fluid, is a single, delicate, tubular filament (fig. 78, 2, *f*), which, when unravelled, is found to be nearly 3 feet in length, and is seen winding, in close and almost inextricable folds, around the middle and hinder parts of the intestine. The termination of this tube, *g*, may be traced to the tail or anal extremity of the worm, where it ends in a filamentary retractile penis, *i*, in which the microscope exhibits a minute receptacle, wherein the seminal fluid accumulates preparatory to its expulsion. During copulation the penis of the male is introduced into the vulva of the female, by which it is firmly embraced, and the different positions which the external parts occupy in the two sexes is evidently an arrangement favourable to their intercourse.

Fig. 79.



Trichina spiralis.

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* Siebold, *loc. cit.*

(429.) The *Trichina spiralis* (fig. 79) is an Entozoon found in immense numbers imbedded in the cellular intervals between the muscular fibres; and in some instances all the voluntary muscles seem full of these creatures, exhibiting, when viewed with the naked eye, an appearance imitated in the annexed figure (fig. 79, *c*). On examining the white specks attentively under the microscope, every one of them is seen to be a flask-shaped vesicle, apparently formed of condensed cellular membrane, in which the minute animal is lodged; and when this outer covering is ruptured, as at *a*, the worm escapes. A magnified view of the Entozoon is given at *b*, coiled up in the position in which it is seen prior to the destruction of the sac that enclosed it. Tho body seems to be filled with granular matter, which escapes when the worm is torn asunder (*d*); but whether it possesses a true alimentary tube is not as yet satisfactorily determined.

CHAPTER VIII.

ECHINODERMATA* (Cuv.).

(430.) The next class of beings which presents itself for our consideration seems, upon a partial survey, to be completely insulated and distinct from all other forms of living creatures; so peculiar is the external appearance and even the internal organization of the families composing it. The casual observer who should, for the first time, examine a star-fish or a sea-urchin, two of the most familiar examples of the ECHINODERMATA met with upon our shores, would, indeed, find it a difficult task to associate them, either to the simpler animals we have already described, or to more perfect forms of existence hereafter to be mentioned; they would seem to stand alone in the creation, without appearing to form any portion of that series of development which we have hitherto been able to trace so continuously.

(431.) But this apparent want of conformity to the general laws of development vanishes on more attentive examination; so that we may not only follow the steps by which every family of this extensive class merges insensibly into another, but perceive that, at tho two opposite points of the circle, the ECHINODERMATA are intimately in relation with the POLYPS on one hand, while on the other they as obviously approximate the Annulose animals, to which the most perfectly organized amongst them bear a striking resemblance.

(432.) It would be impossible within our present limits to do more than lay before the reader the most important types of structure exhibited by the ECHINODERMATA; it must nevertheless be understood that innumerable intermediate families connect the different genera; so that, however dissimilar the examples we have selected for the purpose of elucidating their general habits and economy may appear, the gradations leading from one to another are easily discoverable.

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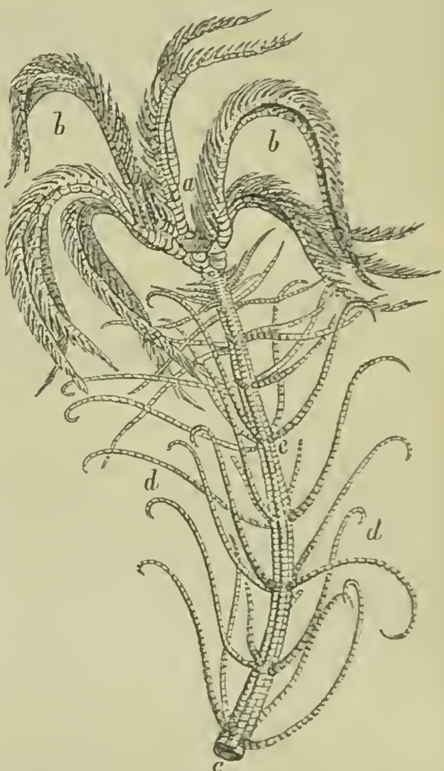
* ἐχῖνος, a hedgehog; δέρμα, the skin.

(433.) CRINOIDÆ.—We have already found that many tribes of Polyps secrete calcareous matter in large quantities, constructing for themselves the solid skeletons or polyparies which generally seem to be placed external to their soft and irritable bodies, but occasionally, as in *Pennatula*, within the living substance. Let us for a moment suppose a polyp supported upon a prolonged stem, and that, instead of depositing the earthy particles externally, they should be lodged in the substance of the polyp itself, so as to fill the pedicle, the body, the tentacula around the mouth, and all the appendages belonging to the animal, with solid pieces, of definite form; such pieces, being connected together by the soft parts, and surrounded on all sides with irritable matter, would thus form a complete internal skeleton, giving strength and support to the entire animal, and at the same time allowing flexure in every direction. A polyp so constituted would obviously, when dried, present an appearance similar to what is depicted in the annexed engraving (fig. 80), representing an Encrinoid Echinoderm in its perfect condition. That animals thus allied to polyps in their outward form have, in former times, existed in great numbers upon the surface of our planet is abundantly testified by the immense quantities of their remains met with in various calcareous strata; but their occurrence in a living state is at present extremely rare: one minute species only has been detected in our own seas*; while specimens of larger growth, such as that represented in the engraving, derived from tropical climates, are so seldom met with, that it is fortunate one or two examples have been found, to reveal

Fig. 80.



Encrinus.

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* Thompson (J. W.), Memoir concerning the *Pentacrinus europæus*. Cork, 1827, 4to.

to us the real structure of a race of animals once so common, but now almost completely extinct. The body of the *Encrinus* (fig. 80, *a*) (or pelvis, as the central portion of the animal is termed by geological writers) is composed of numerous calcareous pieces, varying in shape and arrangement, so as to become important guides to the identification of fossil species; from this central part arise the large rays (*b b*), each furnished with a double row of articulated appendages, which, as well as the arms, are no doubt instruments for seizing prey and conveying it to the mouth, situated in the centre of the body, near the point *a*. This part of the animal, when found in a fossil state, from its resemblance to a flower, has received the common name of a "lily-stone."

(434.) The body above described, with the rays proceeding from it, is supported upon a long pedicle (*e*), divided into countless segments; and upon the sides of the stem, similarly-constructed filamentary branches are fixed (*d d*) at equal intervals. The skeleton of an *Encrinite* consists, therefore, of thousands of regularly-shaped masses of calcareous earth, kept together by the living and irritable flesh in which they are imbedded; and it is to the contractions of this living investment that the movements of the animal are due; but after the death of the creature, and the consequent destruction of its soft parts, the pieces of the earthy framework become separated and fall asunder, forming the fossil remains called "*Trochi*," and known in the northern districts of our own island, where they are very abundant, as "*St. Cuthbert's beads.*"

(435.) Of the internal structure of the Encrinites nothing is satisfactorily known. That they possessed a distinct mouth and anal aperture is evident from the structure of the plates of the body; but this is the extent of our information concerning them*.

(436.) Asteridæ.—In order to convert an Encrinus into an animal capable of locomotion and able to crawl about at the bottom of the sea, little further would be requisite than to separate the body and arms from the fixed pedicle upon which they are supported; we should then have a creature resembling in every particular the Star-fishes. The *Comatula*, for example (fig. 81), one of the lowest of the asteroid Echinodermata, might be looked upon as an animal thus detached. The central part, or body, which contains the viscera, is made up of numerous calcareous plates, having in its centre a stelliform mouth; and near this is a tubular orifice, probably to be regarded as an anus. Around the margin of the central disk arise five stunted arms; but these immediately divide into a variable number of long radiating branches, composed, like those of the Encrinus, of innumerable articulated earthy pieces enveloped in a living and irritable integument. We find, moreover, issuing from the sides of every one of the prolonged rays, a double row of secondary filaments, each containing an internal jointed skeleton, and capable of independent motion. The complicated arms of the *Comatula*, therefore, are not, like those of the Polyp, merely adapted to seize prey, but, from their superior firmness, may be used as so many legs, enabling the animal to travel fron place to place.

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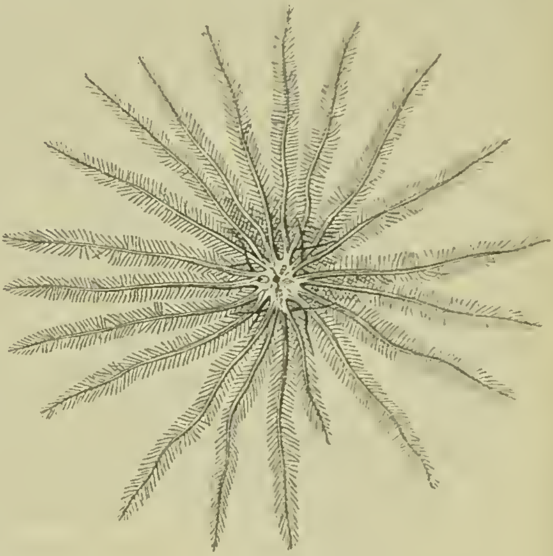
* For a detailed account of the fossil Encrinites, the reader is referred to 'A Natural History of the Crinoidea, or Lily-shaped Animals,' by J. S. Miller. 4to, Bristol, 1821.

Setting out from this point to trace the gradual development of organization in the Echinodermata, we shall observe a progressive concentration of their entire structure. The central part, or visceral cavity, so small in the *Comatula* when compared to the complicated rays derived from it, enlarges in its proportional dimensions as the viscera contained within it become more perfect in their arrangement, whilst, on the other hand, the radiating or polyp form, so visible in *Encrinus* and *Comatula*, becomes obliterated by degrees, until, at length, almost all vestiges of it are lost, or but obscurely recognizable.

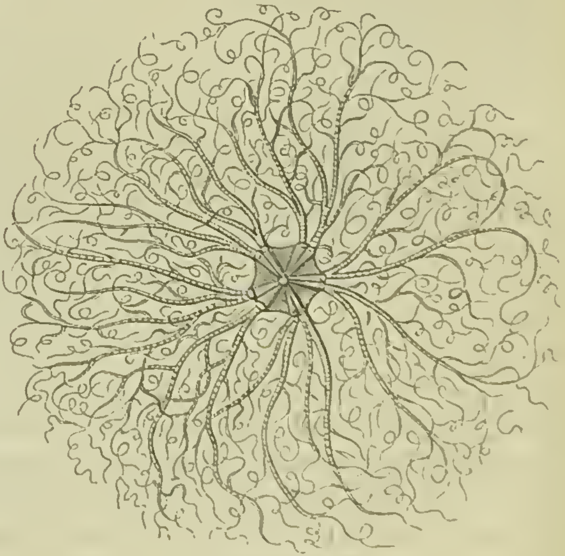
Fig. 81.



Comatula.

In the *Gorgonocephalus* (fig. 82), the proportionate size of the rays, when compared with that of the central disk, still preponderates very considerably, although even here some concentration is manifest. The secondary articulated filaments appended to the rays of *Comatula* are no longer recognizable, their place being supplied by the continual division and subdivision of the rays themselves: the same end, however, is obtained in both cases; for the numerous

Fig. 82.

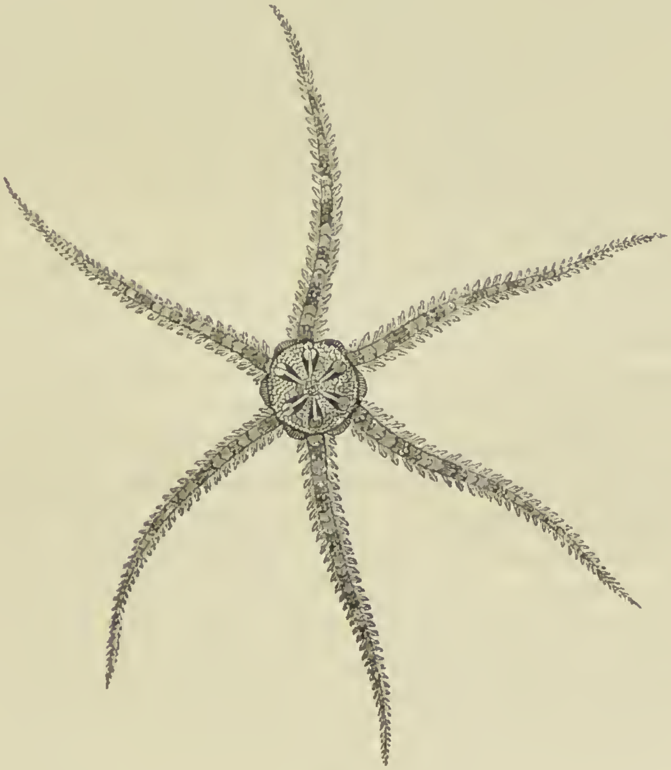


Gorgonocephalus.

jointed and flexible rays of *Gorgonocephalus* still form so many legs, enabling the creature to drag itself along the bottom of the sea, or to entwine itself among the submarine plants, as well as supplying the office of tentacula in securing food.

(437.) Continuing our progress towards more perfect forms of these remarkable animals, we at length arrive at genera in which the rays become divested of all elongated appendages, either in the shape of articulated lateral filaments or dichotomous ramifications. In *Ophiura*, for instance (fig. 83), the rays are long and simple, resembling the tails of so many serpents—a circumstance from whence the name of the family is derived; nevertheless, on each side of every ray we still trace moveable lateral spines, which, although but mere rudiments of what we have seen in *Comatula*, may yet assist in locomotion, or perhaps may contribute to retain the prey more firmly when seized by the arms. The rays themselves are composed of many pieces curiously imbricated and joined together by ligaments, so that they are, from their length and tenuity, extremely flexible in all directions, and serve not only for legs, adapted to crawl upon the ground, but are occasionally serviceable as fins—able to support the animal in the water for a short distance by a kind of undulatory movement. The body, or central disk, is beauti-

Fig. 83.



Ophiura.

fully constructed, being made up of innumerable pieces accurately fitted together. The mouth occupies the centre of the ventral surface, and is surrounded by radiating furrows, in which are seen minute apertures that give passage to a set of remarkable prehensile organs, to be described hereafter: these are calculated to act as suckers, and so disposed as either to fix the body of the animal, or to retain food during the process of deglutition.

(438.) Leaving the *Ophiuræ*, we are led through a long series of almost imperceptible gradations to the Star-fishes (*Asterias*) (fig. 87): in these, from the increased size of the body, the rays are united at their origin, and become so much dilated as to contain prolongations of the viscera lodged in their interior—an arrangement not met with in *Ophiuræ* and other slender-rayed Asteridæ. The dilatation of the central part proceeds, and in the same proportion the rays become obliterated; so that by degrees, the asteroid shape becomes totally lost by the progressive filling up of the interspaces between the rays, and we arrive ultimately at completely pentagonal forms, the sides of the pentagon being perfectly straight lines.

(439.) It is extremely interesting to observe the changes which occur in the nature of the locomotive organs during these diversifications of external figure. We have seen that, in the lower Echinodermata, possessing long and flexible rays, such organs were fully adequate to perform all movements needful for progression; but as the mobility of these parts is diminished by their gradual curtailment and the filling up of the spaces between them, some compensating contrivance becomes indispensably necessary; and accordingly we find an apparatus gradually developed, well calculated to meet the exigences of the case. In *Ophiura* we have already mentioned the existence of protrusible suckers around the opening of the mouth, well adapted, from their position, to take firm hold of food seized by the animal; and it is by increasing the number of such organs that ample compensation is made for the loss of motion in the rays themselves. On examining the lower surface of an *Asterias*, even in those forms which most approximate a right-lined pentagon in their marginal contour, the number of rays will still be found to be distinctly indicated by as many furrows radiating from the mouth, and indicating the centre of each division of the body. These "*ambulacral furrows*," as they are termed, exhibit, when examined in a dried specimen, innumerable orifices arranged in parallel rows, through each of which, when alive, the animal could protrude a prehensile sucker, capable of being securely attached to any smooth surface (fig. 87).

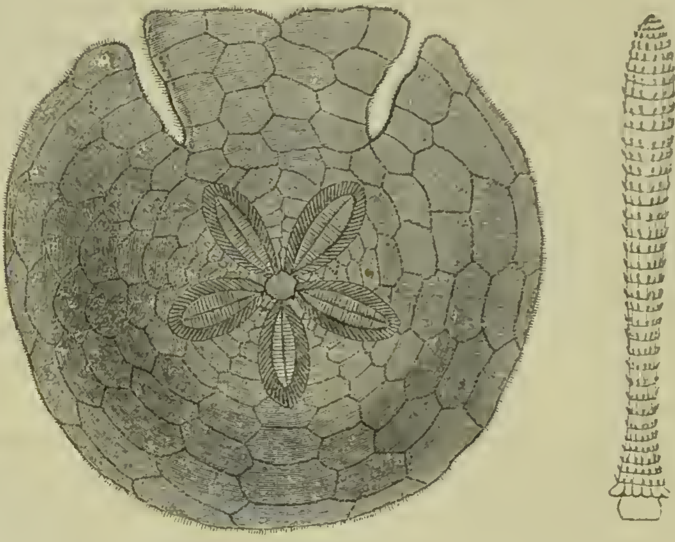
No verbal description can at all do justice to this wonderful mechanism, even leaving out of the question the means by which each individual sucker is wielded (of this we shall speak hereafter); but let any of our readers, when opportunity offers, pick up from the beach one of these animals, the common Star-fish of our coast, which, as it lies upon the sand, left by the retiring waves, appears so incapable of movement, so utterly helpless and inanimate; let him place it in a large glass jar filled with its native element, and watch the admirable spectacle which it then presents. Slowly its tapering rays expand to their full stretch; hundreds of feet are gradually protruded through the ambulacral apertures, and each, apparently possessed of independent action, fixes itself to the sides of the vessel as the animal begins its march. The numerous suckers are soon all employed, fixing and detaching themselves alternately, some remaining firmly adherent, while others change their position; and thus, by an equable gliding movement, the Star-fish climbs the sides of the glass in which it is confined, or scales the perpendicular surface of the submarine rock.

It is not only as agents in locomotion that the ambulacral suckers are used; for, helpless as these creatures appear to be, they are among the most formidable tyrants of the deep, as will be readily admitted by any one who watches them in the act of devouring prey. When seizing its food, the rays of the *Asterias* are bent towards the ventral aspect, so as to form a kind of cup, in the centre of which is the opening of the mouth. The cup thus formed will, to a certain extent, lay hold of a passing victim; but, without other means of securing it, the grasp would scarcely be very formidable to animals possessed of any strength: armed, however, as the rays have been found to be, with hundreds of tenacious suckers, escape is almost impossible; for prey, once seized, is secured by every part of its surface, and, in spite of its utmost efforts, is speedily dragged into the mouth and engulfed in the capacious stomach, where its soft parts are soon dissolved.

But to continue our survey of the class before us. Having arrived at the point at which, by the diminution of the rays and consequent extension of the central part, the body has assumed a pentagonal outline, we may now advance in an equally gradual manner to those globular species of which the *Echinus* or *Sea-urchin* is the type or most perfect example.

(440.) Echinidæ.—In the *Scutellæ* (fig. 84), we have a flat and shield-like body, in which even the angles of the margin are lost, and the whole circumference acquires a circular form; but still the five radiating ambulacra are visible upon the centre of the disk, although evidently imperfectly developed when compared with those of the Asteridæ above-mentioned. The nature of the integument has, in fact, become so changed, that another modification of the locomotive organs is now imperatively called for; and the means of progression are therefore proportionately altered. In the Asteridæ, the integuments, especially upon the dorsal aspect, are always more or less composed of a coriaceous material, or, at least, of solid pieces so articulated together as to permit of considerable flexibility: but in the Echinidæ the nature of the external covering is very different; for these creatures seem completely encased in a dense calcareous shell, composed of numerous angular pieces accurately fitted together and incapable of movement. The *Scutellæ*, moreover, bury themselves beneath the surface of the sand—a situation in which suckers would be of little use, but for which these animals are admirably adapted by a contrivance not less calculated to excite the admiration of the observer. The exterior of the shell is entirely covered with minute appendages resembling, when seen with the naked eye, delicate hairs; but these, when examined under a microscope, are found to be spines of most elaborate structure, as is evident from the magnified view of one represented in the annexed figure (fig. 84). Innumerable as these spines are, every one of them is articulated to the shell by a kind of ball-and-socket joint, and susceptible of being moved in all directions; so that by their combined efforts the *Scutella* can speedily bury itself, either for the purpose of procuring food, or of eluding observation.

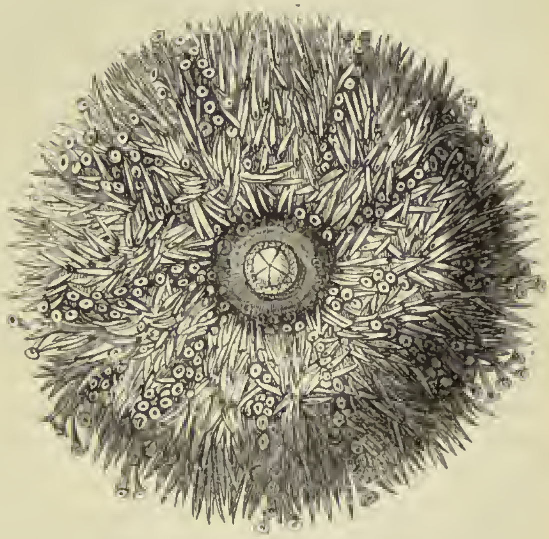
Fig. 84.



Scutella.

(441.) From the flat *Scutellæ*, the passage to the globose ECHINIDÆ is uninterrupted; and a beautiful series of connecting forms (many still existing as living species, but a still greater number found only in a fossil state) demonstrate the progressive expansion of the shell, and its conversion into the spherical figure seen in the *Echinus esculentus* (fig. 85). The Echinus in shape resembles an orange, its dense calcareous crust enclosing the viscera within its cavity, while the locomotive apparatus is placed upon the external surface. The mouth is a simple orifice in the shell, placed at one extremity of its axis; and through it, as represented in the figure, the points of five singular teeth project externally; while the anal aperture is situated at the opposite pole of the sphere. The instruments of locomotion occupy the entire superficies of the shell, and consist of two distinct sets of organs adapted to different uses. The first consists of a multitude of sharp purple spines, every one of which is articulated to a distinct and prominent tubercle whereon it moves. These numerous spines, therefore, which are essentially similar in their office to those we have already described in *Scutella*, differing only in proportionate size, are so many inflexible legs, upon which the Echinus rolls itself from place to place, or by their assistance it can bury itself in the sand with the greatest facility. But these wonderfully constructed animals are by no means confined to this mode of progression; for, impossible as it might appear from their outward appearance, they are able to climb rocks in search of food, and thus destroy the corallines and shell-fish upon which they principally feed. In order to effect this, we find the shell perforated with ten rows of small orifices, so disposed as to form five pairs of ambulacra extending from one pole to the other: through these apertures a system of long suckers is made to issue, which, protruding (as represented in fig. 85) beyond the points of the spines, can be firmly fixed to any smooth surface, and, like the suckers of *Asterias*, become locomotive agents.

Fig. 85.

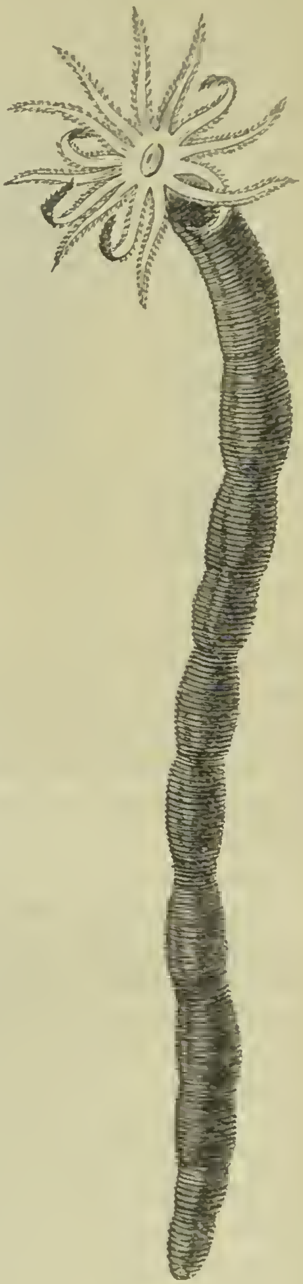


Echinus esculentus.

(442.) Holothuridæ.—Having traced the development of the Echinodermata from the polypiform *Encrinite* to the globular *Echinus*, we now shall find them perceptibly approximate an annulose or worm-like form. In the *Holothuria* (fig. 100), the commencement of this change is perceptible: instead of being composed of hard, calcareous pieces, the integuments of the body now become soft and irritable, a few thin laminæ of earthy matter around the mouth being the only vestiges of the shell, and the spines, of course, are no longer met with; the suckers, however, remain, and, when protruded through innumerable apertures distributed over the surface of the body, they still form the principal instruments of progression.

(443.) Fistularidæ.—At length, in the last division of the class, even the locomotive suckers are lost, and the only external resemblance left between the now worm-like body and the forms above enumerated, is met with in the radiating tentacula that surround the mouth. The apodous Echinodermata ("Echinodermes sans pieds" of Cuvier) have indeed been expunged from the list of radiated animals by some modern writers; but in every point of their internal structure we shall find them offer too many points of similarity to permit of their expulsion from the class under consideration, although they evidently form the connecting link between the Radiata and the lowest families of the Annulose division of the animal kingdom. The genus *Fistularia* (fig. 86) strikingly exhibits an approximation to the outward form of the Annelida; and the anatomy of these creatures, which we shall afterwards consider, equally indicates the affinities that unite them.

Fig. 86.



Fistularia.

(444.) We have already, when speaking of the general division of the Echinodermata, put the reader in possession of all that is satisfactorily known concerning the structure of the Crinoid* genera,—our knowledge of those singular animals being entirely derived from the exterior conformation of a few recent species, and from the mutilated skeletons of fossil Encrinites, which exist in such abundance in the limestone strata of our own country.

(445.) Commencing, therefore, with the Asteridæ†, we shall now enter at once upon the consideration of the anatomy of such species as have been most carefully examined, and merely notice incidentally the modifications which occur in the disposition of various organs in kindred genera.

(446.) On examining a living *Asterias*, the outer covering of its body is found to be composed of a dense coriaceous substance, in which numerous calcareous pieces are apparently imbedded. The coriaceous integument is generally coloured externally with lively tints, and is evidently possessed of considerable irritability, as it readily shrinks under the knife, or upon the application of various stimuli. When cut into, it has a semicartilaginous hardness; and fibrous bands, almost resembling tendon in their aspect, may be seen to radiate from the centre of the body towards the extremities of the rays. There is no doubt that the movements of the rays are effected by the contractions of this fibrous membrane, and that, especially in the most polyp-like forms, as in *Comatula* and *Gorgonocephalus*, the irritable skin is the principal agent in effecting locomotion.

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* κρίνον, a lily; εἶδος, likeness.

† The name of this family and of its typical genus is derived from ἀστήρ, a star.

(447.) Besides the calcareous matter deposited in its interior, this outer covering of the Star-fish appears to furnish several secretions of different descriptions. The colouring matter upon its surface is no doubt one of these; as is a reddish fluid which exudes from the integument of *A. rubens*, and is of so caustic a quality as occasionally to produce great irritation of the skin in persons by whom individuals of this species are incautiously handled: moreover, in *A. aurantiaca* the whole animal is coated with a thick mucus, so dense and filamentous that it may be raised in thin films resembling a cobweb, and might easily be taken for a cuticular covering.

(448.) The exterior of the body is generally rendered rough and uneven by various structures, either imbedded in the substance of the coriaceous skin or projecting from its external surface. We have already described the articulated pieces attached to the rays of *Comatula* and others, which seem to be the most perfectly developed forms of these cutaneous appendages. In the common Star-fish of our own coast, similar spinous processes, but composed of only one calcareous piece, are attached to the inferior margins of each ray, sometimes in several rows; and, being still moveable, they may be useful in seizing prey, or even as assisting in progression. Upon the dorsal aspect of the body are other calcareous projections, exhibiting a great variety of forms, so as to render the entire surface of the animal uneven and tuberculated.

(449.) But the most remarkable appendages to the integument of the Asterias are minute bodies, which have been named by authors *Pedicellariæ*, and have been looked upon by many naturalists as distinct animals, allied to Polyps in structure, and living parasitically upon Star-fishes and other Echinodermata. Each of these curious processes consists of a short stem, fixed by one extremity to the skin of the Asterias, and terminating at the opposite end in two or three points resembling, in some respects, the prongs of a fork: the stem itself does not seem to be perforated by any canal; nevertheless the terminating points are found to be highly irritable, and quickly seize hold of any minute body placed between them. Some writers regard these bodies as organs of prehension, used under certain circumstances for fixing the animals that possess them; but, from their small size and general appearance, they seem but ill adapted to such an office.

(450.) The skeleton or calcareous framework imbedded in the skin of the Asteridæ is by no means the least remarkable part of their structure: this consists of several hundred pieces, variously disposed, and for the most part fitted together with great accuracy, being either firmly soldered to each other, as we have seen them to be in the formation of the calcareous box that constitutes the central portion of *Ophiura*, or united by ligaments, so as to allow of a considerable degree of motion to take place between them, as in the rays of *Ophiura*, *Gorgonocephalus*, and other Asteroid forms.

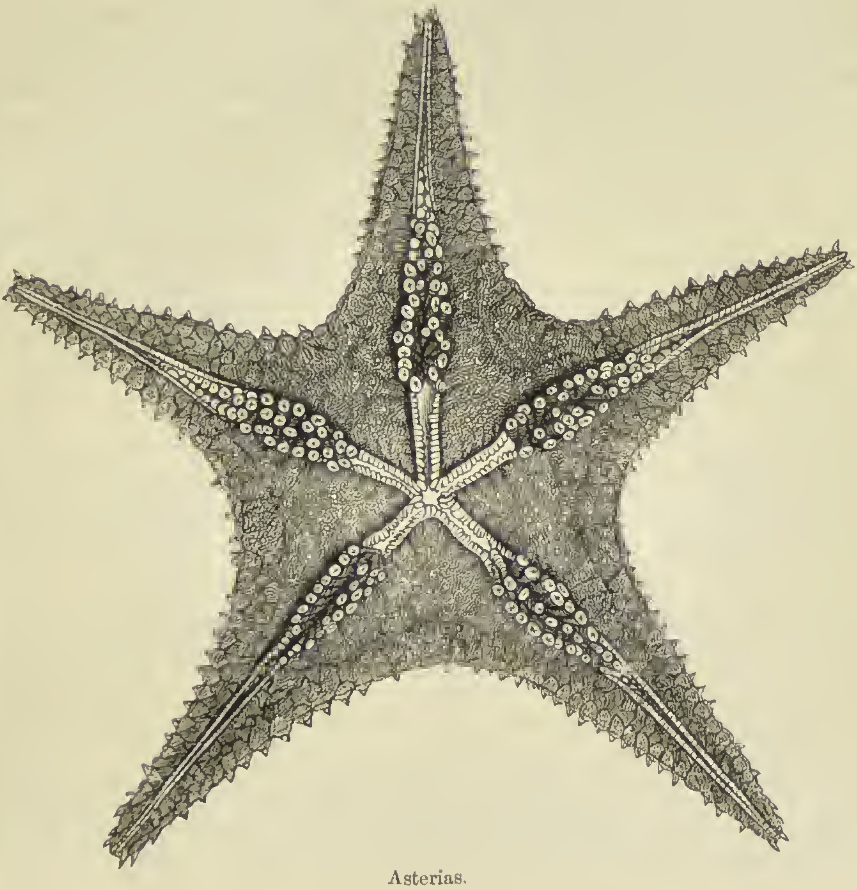
(451.) In the generality of Star-fishes, the arrangement, and indeed the entire character of the calcareous plates, differs materially in different parts of the body; and even in the same species considerable modifications are observable. In the coriaceous integument forming the dorsal parietes of the animal, the pieces in many cases seem rather to be represented by calcareous granules disseminated through the interior of the skin; in other cases they are arranged in lines anastomosing with each other in all directions, so as to represent, when the skin is dried, a rude network of solid particles, upon the exterior of which the various cutaneous appendages already noticed are sustained.

(452.) It is, however, upon the ventral aspect of the Asterias that the skeleton assumes its most perfect development; the floor of every ray is made up of a continuous series of detached pieces, or vertebræ, as they are generally called, fitted to each other and united by a strong ligamentous substance, so as to form a succession of joints, upon which the flexibility of the ray depends. The pieces around the mouth constitute a strong circular framework enclosing the oral aperture, from which, as from the centre, the rest of the skeleton radiates. The joints forming the floor of the ray succeed to this; these are partially represented in fig. 90, where, the soft parts having been removed from the ray marked *b*, their general arrangement is displayed.

(453.) The vertebræ, as they are called, when thus exposed are found to be individually composed of several pieces, and each is articulated by oblique facets to those which precede and follow it,—a kind of union that admits of considerable motion, and provides for the flexibility of the ray, so as to render it capable of executing movements requisite for the purpose of progression, or of seizing prey. The connexion of the vertebræ is effected in such a manner, that between each pair of calcareous plates minute orifices are left, which in the entire state of the ray are seen to be arranged in a quadruple series; these holes give passage to the locomotive suckers, and from this circumstance have been named the *ambulacral holes*, while the furrows, seen upon the ventral surface, into which they open are designated the *ambulacral grooves*.

(454.) The suckers, which at the will of the animal are protruded through the ambulacral apertures, forming the principal agents whereby locomotion is effected, next require our notice. In the annexed figure (fig. 87) they are seen fully extended, projecting for some distance

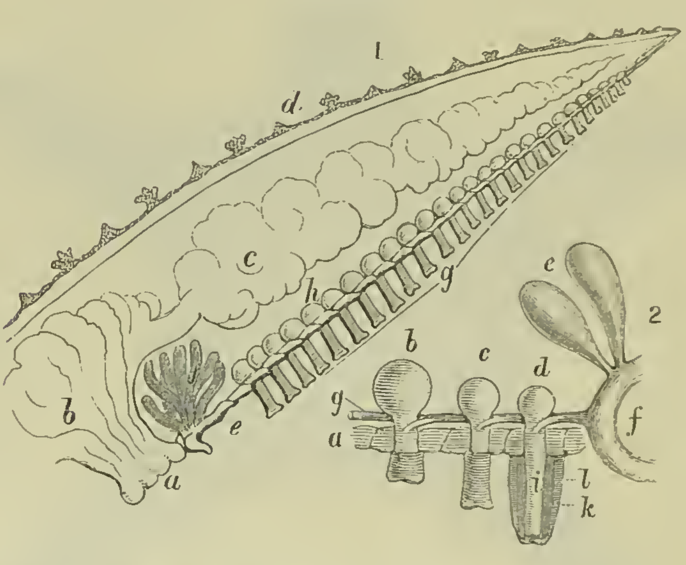
Fig. 87.



Asterias.

beyond the margins of the ambulacral grooves that occupy the middle of each ray, every one of them being furnished at its extremity with a sucking disk, adapted to take firm hold upon any smooth surface. The mechanism whereby these suckers, or feet, as they are usually called, are extended from the body and again retracted, is very simple. That portion of each foot which is external to the shell is a muscular tube, closed at one extremity, namely that whereunto the sucker is appended; whilst by the opposite it communicates, through the corresponding ambulacral hole, with a globular contractile vesicle situated within the body of the animal. Both the tubular foot, and the vesicle appended to it, are endowed with a power of independent action; so that, if the vesicle contracts, the fluid within it is forced into the external tubular portion of the organ, which thus becomes distended and rendered erect; but if, on the other hand, the muscular tube shrinks in turn, the contained fluid is forced back again into the internal vesicle, and the whole foot collapses. The arrangement referred to will be easily intelligible on reference to the annexed rough diagram, which represents a longitudinal section of one of the rays of the Asterias depicted above. The internal vesicles (fig. 88, 1, *h*) occupy the floor of each segment of the body; and when viewed from above (fig. 90, *d*), the entire series resembles strings of transparent beads placed above the rows of ambulacral apertures, through which they communicate with the tubular feet (fig. 88, 1, *g*). In fig. 88, 2, three of these organs are represented in different states of extension, and their whole structure is developed. The foot (*d*) is shown protruded to its full extent; the vesicle, much contracted, has forced the fluid which it contained into the external tube (*i*), whereby it is rendered tense and prominent. The muscular coats that invest the exterior of the protruded portion are likewise depicted; the internal layer (*k*), immediately in contact with the membranous canal continued from the vesicle, is made up of longitudinal bands passing from the root of the organ towards the sucker at its extremity, while the outer layer (*l*) consists of circular fibres,—an arrangement evidently adequate to the performance of all required movements.

Fig. 88.



1. Diagrammatic section of a Star-fish: *a*, mouth; *b*, stomach; *c*, intestiniform cæca; *d*, dorsal surface; *e*, ambulacral plates; *f*, ovarium; *g*, tubular feet; *h*, internal vesicles. 2. Diagram representing the suckers in different states of extension: *a*, ambulacral plates; *b*, *c*, *d*, internal vesicles; *e*, *f*, *g*, vascular system; *i*, tubular foot, laid open to exhibit *k*, *l*, its muscular coats.

(455.) The other portions of this diagram represent the feet in different stages of protrusion: in fig. 88, 2, *c*, the vesicle being partially contracted, the tubular portion is seen in a medium state of distention: and at *b*, the sucker is shown in a still more retracted state, the contained fluid having been completely expelled from the muscular tube and driven back into the vesicle, which is distended to the utmost.

(456.) The fluid that thus fills the suckers, and performs so important a part in causing all their movements, is not secreted by the vesicles in which it is contained, but is conveyed into them by a special vascular apparatus (fig. 88, 2, *g*, *f*), from which branches are given off to each tube. The nature of the fluid, however, and the arrangement of the vessels through which it flows will be more properly discussed hereafter.

(457.) The whole inner surface of the elaborately-constructed box that forms the skeleton as well as the integuments of the Star-fish is lined by a thin membrane, aptly enough called the *peritoneum* ; for, like the serous tunic so named in higher animals, it not only spreads over the walls of the body, but is reflected therefrom upon the contained viscera, so that they are completely invested by it, each viscus having a distinct mesenteric fold whereby it is supported and retained *in situ.*

(458.) The mouth of the Asterias occupies the centre of the lower surface of the body (fig. 88, 1, *a*). It is usually described as being a simple orifice, entirely destitute of teeth, although it is not improbable that the osseous ring around it, and the articulated spines thereunto attached, may, to a certain extent, perform the office of a dental apparatus.

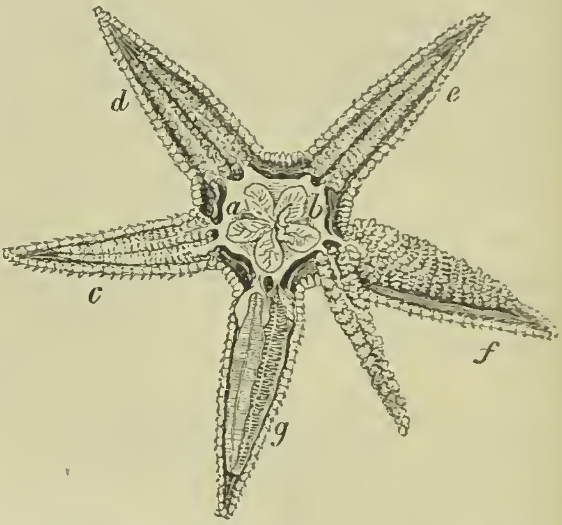
(459.) The œsophagus is very muscular, and susceptible of great dilatation, its parietes being gathered into deep longitudinal folds. The stomach (fig. 88, 1, *b*) is a wide, sacculated bag, occupying the central portion of the body, and, like the œsophagus, is evidently calculated to undergo considerable distention. There is no anal orifice ; and consequently, as in the Polyps, the indigestible parts of the food are again expelled through the mouth. The walls of the stomach, as well as those of the œsophagus, contain muscular fibres, and are further strengthened by fibrous bands, apparently of a ligamentous character, derived from the peritoneal covering that spreads over its outer surface. Ten narrow canals open by as many distinct orifices into the sides of the stomach, each of which, after a short course, expands into a voluminous cæcum (fig. 88, 1, *c*).

(460.) The whole of the digestive apparatus is displayed in fig. 89 : every one of the five rays contains two of tho cæcal prolongations derived from the stomach or central bag (*a*) ; and in the rays marked *c*, *d*, *e*, these organs are represented *in situ*, but at *f* they are seen raised from their natural position and carefully unravelled, so as to display more distinctly their complicated structure. When thus unfolded, the cæca present an arborescent appearance, the central canal being dilated into numerous lateral sacculi, from which, in turn, secondary pouches are given off ; and in this manner innumerable ramifications are formed, so that the extent of internal surface is enormously increased, as may be seen in the ray *g*, wherein, the upper walls of the cæca having been removed, their sacculated internal structure is rendered visible.

(461.) With respect to the exact office of these capacious appendages to the stomach, there exists some diversity of opinion.

(462.) It is scarcely possible that they can be at all instrumental in the digestion of food, the passages whereby they communicate with the central cavity being too narrow to admit any solid substance into their interior; the digestive process would therefore seem to be entirely accomplished by the receptacle into which the food is first introduced. But there is every evidence to prove that, although they can have little part in digestion, the cæca are intimately connected with the absorption of nutriment; and thus, although possessing no excretory orifice, they must be looked upon as strictly analogous in function to the intestinal canal of other animals: the great extent of surface which they present internally would alone lead to this supposition, even did not the nature of the material usually found in them, namely, a pultaceous creamy fluid, evidently a product of digestion, abundantly confirm this view of their nature. The matter seems, however, to be put beyond a doubt by the arrangement of the vascular system connected with these organs, as the veins that ramify so extensively through their walls are here, as in other Echinodermata, the only agents by which the absorption of chyle can be effected: this will be evident when we examine the organs subservient to the circulation of the nutritious fluids.

Fig. 89.



Digestive apparatus of Asterias: *a*, stomach; *b*, hepatic (?) glands; *c*, *d*, *e*, cæcal appendages *in situ*; *f*, the same unravelled; *g*, the same laid open, showing their sacculated interior.

(463.) Those physiologists who have adopted a different view of the nature of the cæcal appendages to the stomach, consider them to be adapted to the secretion of some fluid, and probably representing a biliary apparatus. Their enormous extent, however, would alone lead us to dissent from such a conclusion, more especially as another organ has been pointed out to which the functions of a liver have been assigned. This is situated upon the base of the stomach (fig. 89, *b*), and is a yellow or greenish-yellow racemose sacculus, which opens into the bottom of the digestive sac by a free aperture; the contents of this organ, moreover, resemble bile both in taste and colour[*].

(464.) In the slender-rayed genera, such as *Ophiura*, the cæcal appendages are not met with; but their deficiency appears to be supplied by the plicated walls of the stomach itself, the numerous folds of which resemble lateral leaflets attached to the central cavity. We are unacquainted with the precise organization of the alimentary canal in *Comatula*; but, from the orifices visible in the shell, it would appear that in this genus, as well as in some Crinoid species, the digestive tube was furnished with an anal aperture.

(465.) The Star-fishes, grossly considered, might be regarded as mere walking stomachs; and the office assigned to them in the economy of nature, that of devouring all sorts of garbage and offal that would otherwise accumulate upon our shores. But, as we have already seen, their diet is by no means exclusively limited to such materials, since crustaceans, shell-fish of various kinds, and even small fishes, easily fall victims to their voracity. Delle Chiaje found a human molar tooth in the stomach of an individual which he examined. Neither is the size of the prey whereon they feed so diminutive as we might suppose from a mere inspection of the orifice representing the mouth; for not only is this extremely dilatable, but, as we have found to be the case in the Actiniæ, the stomach is occasionally partially inverted, in order more completely to embrace substances about to be devoured. Shell-fishes are frequently swallowed whole; and a living specimen of *Chama antiquata*, Linn., has been taken entire from the digestive cavity of an Asterias. It appears, moreover, that it is not necessary for testaceous mollusca to be absolutely swallowed, shells and all, to enable the Asteridæ to obtain possession of the enclosed animal, as they would seem to have the power of attacking large oysters, to which they are generally believed to be peculiarly destructive, and of eating them out of their shells. The ancients believed that, in order to accomplish this, the star-fish, on finding an oyster partially open, cunningly inserted one of its rays between the valves, and thus gradually insinuating itself, destroyed its victim[†]. Modern observations do not, as far as we are aware, fully bear out the above opinion of our ancestors as to the mode in which star-fishes attack oysters, although the destruction that they cause is pretty generally acknowledged. The observations recorded by M. Eudes Deslongchamps upon this subject, however, are exceedingly curious*. As the waves had receded from the shore, so as to leave only one or two inches of water upon the sand, he saw numbers of *Asterias rubens* rolling in bunches, five or six being fastened together into a sort of ball by the interlacement of their rays. He examined a great number of such balls, and constantly found in the centre a bivalve mollusk (*Mactra Stultorum*, Linn.) of an inch and a half in length. The valves were invariably opened to the extent of 2 or 3 lines; and the star-fishes were always ranged with their mouths in contact with the edges of the valves.

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[*] Delle Chiaje.

[†] This may be gathered from Aldrovandus, who writes as follows: "Alii ostrearum hostes sunt Stellæ marinæ molli crustâ intectæ, verò tam crudeliter (ut Ælianus, lib. ix. cap. 22, ait) inimicæ ut hæ ipsas excedant et conficiunt. Ratio insidiarum quas eis moliuntur ejusmodi est. Cùm testacea suas patefaciant conchas, cùm vel refrigeratione egent, vel ut aliquid pertinens ad victum incidat; eæ, uno de suis sive cruribus sive radiis intra testas ostreæ hiantis insito eas claudi prohibente, carne implentur" (Testac. lib. iii. p. 487). Thus likewise Oppian:—

"Sic struit insidias, sic subdola fraudes
Stella marina parat, sed nullo adjuta lapillo
Nititur, et pedibus scabris disjungit hiantes."

(466.) On detaching them from the shell which they thus imprisoned, he found that they had introduced between the valves large rounded vesicles with very thin walls, and filled with a transparent fluid. Each Asterias had five of these vesicles ranged around its mouth: but they were of very unequal size; generally there were two larger than the rest, equal in size to large filberts, while the other three were not bigger than small peas. These vesicles appeared to be attached to the Asterias by short pedicles; and at the opposite end of each was a round open aperture, through which the fluid contained in the vesicle flowed out, drop by drop. No sooner was the animal detached from the shell that it was thus sucking, than the vesicles collapsed and became no longer distinguishable. The *Mactræ* were all found to be more or less devoured, some having only their adductor muscles left; but, however little they had been injured, all had lost the power of closing their valves, and were apparently dead: nevertheless there was nothing to lead to the supposition that only dead shell-fishes were attacked; so that it is difficult to imagine how the delicate vesicles above described escaped injury from the closing of the valves. M. Deslongchamps thinks that probably the Asterias pours into the shell a torpifying secretion, and thus ensures the death of its victim.

(467.) The absorption of the nutritious portions of the food in the Echinodermata is entirely accomplished by the veins distributed upon the coats of the digestive cavities, so that the chyle resulting from digestion is at once introduced into the vessels appropriated to circulation.

(468.) In *Asterias*, the intestinal veins form a fine vascular network, covering the stomach and the ten digestive cæca. The venous trunks derived from all these sources unite to form a circular vessel (fig. 90. *c*), which likewise receives branches derived from the ovaria and other sources.

(469.) The circular vein thus formed, which seems to be the common trunk of the venous system, communicates with another vascular circle placed around the mouth (*s*), by means of a dilated vertical tube of communication (*f*), which, from its muscular appearance and great irritability, Tiedemann regards as being equivalent in function to a heart. The circle around the mouth (*s*) would seem to be arterial in its character, and branches are derived from it which supply the various viscera of the body.

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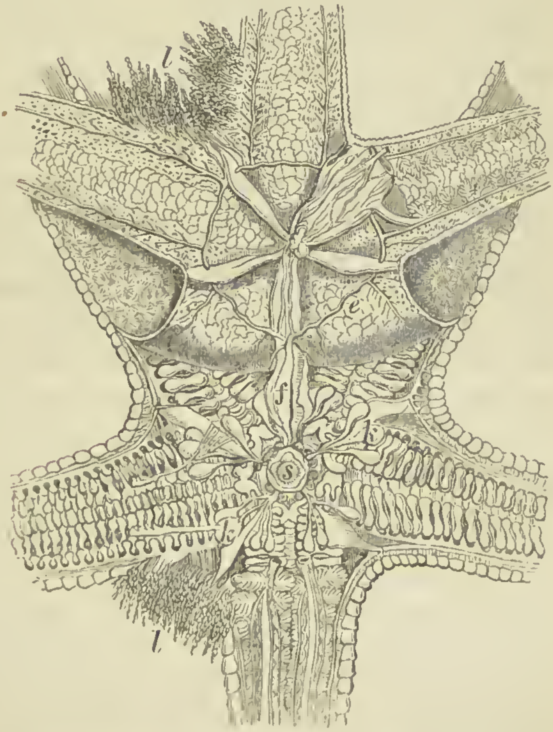
* Bulletin des Sciences de M. le Baron Férussac, vol. x. p. 296.

(470.) But, besides the vessels above described, apparently so disposed as to collect and distribute the nutrient fluids, there is another set of canals appropriated to the supply of the numerous vesicles connected with the locomotive suckers (§ 456); these Tiedemann regards as being totally unconnected with the vascular system properly so called, and considers the fluid contained in them as quite of a different nature. Delle Chiaje, on the contrary, asserts that the two sets of vessels are derived from each other, and describes a peculiar apparatus connected with them as performing an important part in effecting the protrusion of the suckers.

(471.) The circular vessel around the mouth, which forms the central receptacle of the vascular system, resembles a sinus analogous to those of the dura mater in man, and is lodged in a groove between the oral circle of vertebræ and the pieces of the skeleton articulated therewith. Connected with the sinus above mentioned, and placed regularly in the interspaces between the rays, are several oval vesicles (fig. 90, *k k*), filled with a reddish-coloured transparent fluid. These vesicles, which in *Asterias aurantiaca* are seventeen in number, communicate by distinct ducts with the central sinus, and are regarded by Delle Chiaje as reservoirs wherein the nutritive fluids accumulate until expelled by the contraction of the vesicles. Besides the arteries above described as arising from the vascular circle around the mouth, accord-

Fig. 90.



Asterias aurantiaca opened from above: *a*, dorsal parietes reflected; *b*, *c*, *d*, floor of the rays, exhibiting the ambulacral vesicles; *e*, dorsal circular vessel; *f*, heart; *s*, circular vessel surrounding the mouth; *k k*, ampullæ Polianæ.

ing to the author last mentioned, vessels are given off that communicate with the ampullæ connected with the ambulacral suckers, apparently for the purpose of supplying to them the fluid which they contain. These vessels are seen to run along the floor of each ray, and to give off lateral branches communicating with every vesicle, as represented in the enlarged sketch (fig. 88, 2, *g*). By this arrangement it would seem that the contractile organs (fig. 88, 2, *e*) appended to the vascular sinus (*f*) are in reality antagonistic to the tubular structure of the feet, and serve as receptacles for fluid, which, by their contraction, they can force into the whole system of locomotive suckers whenever the feet are brought into action.

(472.) The above view of the arrangement of the vascular system of *Asterias* is, however, by no means universally admitted to be correct. Professor Sharpey agrees with Tiedemann in the opinion that the vessels of the feet form a system perfectly distinct from that of the blood-vessels, and even supposes that the fluid by which the ambulacral tubes become distended is neither more nor less than pure sea-water.

(473.) In the Echinodermata therefore there are,—1st. The cavity of the body (*i. e.*, the spacious interval which separates the digestive from the tegumentary system), filled with a fluid designated *chylaqueous*. 2nd. The protrusile suctorial feet, occupied by another class of fluid (this system constitutes the water-vascular system of Tiedemann and Müller). 3rd. The blood-vascular system of Tiedemann, Delle Chiaje, Valentin, Agassiz, Dr. Sharpey, and Müller. These three systems are generally regarded as distinct and independent.

(474.) The mass of fluid occupying the visceral cavity of the Echinoderms (bounded on one side by the digestive system, on the other by the integuments) has been generally described as consisting purely of sea-water admitted *directly* from without, through the skin, for the exclusive purpose of aërating the blood proper, said to circulate in a capillary system of vessels wrought in the solid parietes circumscribing the cavity. In the Asteridæ, Echinidæ, Ophiuridæ, and Ophiocomidæ, it cannot be denied that the cavity itself is the anatomical homologue of a real perigastric cavity; while in the Holothuridan and Sipunculidan genera it presents itself as a chamber filled with a chylaqueous compound, under the form of a thickly-corpusculated milky fluid organized in a high degree; and in *Sipunculus* it would seem that the cephalic appendages, as well as the whole tegumentary system, are organized with especial reference to the aëration of this fluid.

(475.) The skin is *fenestrated*; that is, at regular intervals the muscular layer disappears, and an interval results, of elliptical figure, covered by only a single layer of epidermis. It is a simple musculo-membranous partition intervening between the chylaqueous fluid within and the surrounding element without; and *through* this veil the two divided fluids interchange their gases. The tentacles are merely hollow musculo-membranous appendages, lined *within* and *without* by a ciliated epithelium. A few proper blood-vessels reach their bases from the circular vessel; but no trace whatever of a vascular plexus in the structure of these parts can be detected. The inference is that the tentacles are designed for the oxygenization of the chylaqueous fluid. To the genus *Holothuria* the same observations are strictly applicable; but although attenuated at regular points, with a view to approximate as closely as possible the chylaqueous fluid to the external medium, no open perforation anywhere exists in the tentacular or tegumentary processes. The surrounding fluid therefore cannot penetrate directly from without into the peritoneal cavity; it is introduced through the mouth and digestive system.

(476.) Before quitting this part of our subject, we must briefly mention a singular organ, apparently intimately connected with the circular vessel around the mouth, and called by Tiedemann the *sand-canal.* This organ is represented in fig. 90, enclosed in the samo sheath as the dilated vessel, *f*, upon the right side of which it is placed; it communicates by one extremity with an isolated calcareous mass, of a rounded figure, called the madreporic plate, seen upon the exterior of the dorsal surface of the Star-fish, while by its opposite extremity it opens into the circular sinus that surrounds the mouth. The tube itself Dr. Sharpey describes* as being about the thickness of a surgeon's probe, and composed of rings of calcareous substance connected by a membrane; so that, viewed externally, it is not unlike the windpipe of a small animal. On cutting it across, it is found to contain two convoluted laminæ, of the same nature as its calcaroous parietes, which are rolled upon themselves in a longitudinal direction, in the same manner as the inferior turbinated bones of an ox. The convoluted arrangement becomes more complete towards the upper end of the tube, where the internal laminæ, as well as the external articulated portion, join the dorsal disk, appearing gradually to become continuous with its substance. The use of this curious organ is quite unknown, although a variety of conjectures have been hazarded upon the subject. The most probable appears to be that of Dr. Sharpey, who suggests that, should the fluid which distends the feet, and the vessels connected with them, be indeed sea-water, it may be introduced, and perhaps again discharged, through the pores of the disk, by means of the calcareous tube, which will thus serve as a sort of filter to exclude impurities.

(477.) Apparently with a view to ensure a continual circulation of aërated fluids through all parts of the system, the entire surface of the membrane that lines the shell, as well as that which forms the external tunic of the digestive organs, has been found to be covered with multitudes of minute cilia, destined by their ceaseless action to produce currents passing over the vascular membranes, and thus to keep up a perpetual supply of oxygenated water to every part*. But it is not only on the peritoneal surfaces that the existence of cilia has been detected; they are found to be extensively distributed over the external surface of the body, within the cavities of the tubular feet, and even over the whole internal lining of the stomach and cæca.

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* Cyclopædia of Anatomy and Physiology, art. "ECHINODERMATA."

(478.) "In *Asterias rubens*," says Dr. Williams, "it can be distinctly demonstrated that no open perforations exist in any part of the integumentary parietes. The membranous processes communicating with the visceral cavity can be proved, by injection, to be cæcal at their distal extremities. It is easy to repeat and confirm the observation of Dr. Sharpey, that the corpuscles of the visceral fluid advance to the distal end of these processes, and then return, under the impulse of ciliary agency. Nevertheless, although an injection so thick as size will not escape through these membranous processes, a thinner fluid, such as coloured water, will slowly ooze through; it is not, therefore, improbable that an interchange of the fluids may to some extent occur through endosmose. The microscope renders it certain that the hollow membranous processes filled by the fluid of the visceral cavity, in *Asterias*, bear in their parietes no trace of true blood-vessels: they are lined within and without by vibratile epithelium, and composed only of interlacing elastic fibres; and consequently their only office seems to be that of exposing the chylaqueous fluid to the renovating influence of the surrounding medium. In *Asterias*, this fluid approaches simple sea-water closely in its physical properties. It is, however, in reality a dilute, albuminous, opalescent solution. It is charged scantily with imperfectly formed corpuscles, always the same in the same species: and the proposition may now be confidently affirmed, that in the Echinodermata the chylaqueous fluid (*i. e.* the contents of the visceral cavity) is itself first aërated, and that by means of a machinery of soft parts it then aërates the blood proper."

(479.) The organs belonging to the reproductive system in the *Asteridæ* exhibit the greatest possible simplicity of structure. The ovaria (fig. 88, 1, *f*) are slender cæca, arranged in bunches around the œsophagus, two distinct groups being lodged at the origin of each ray. In *Asterias aurantiaca* (fig. 90), the excretory ducts are not easily seen: but in the Twelve-rayed Star-fish, especially if examined when these organs are in a gravid state, each ovary may be observed to communicate externally by a wide aperture that perforates the osseous circle encompassing the mouth.

(480.) The generative organs of the male individuals exactly resemble those of the female, and are only distinguishable by the presence of *spermatozoa* in their interior. The process of reproduction† usually occurs during the spring months, at which period the ovaria of the females are found distended with eggs, wherein the vesicles of Purkinje and of Wagner are distinctly recognizable. These ova are found in the ovaria in different stages of development, and are laid in successive batches at different intervals.

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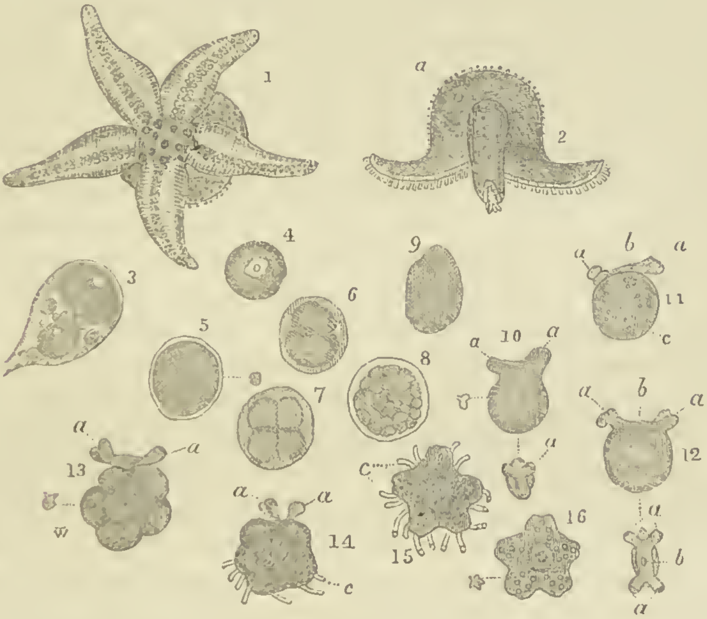
* See the article "Cilia," by Dr. Sharpey, in the 'Cyclopædia of Anatomy and Physiology.'

† Mémoire sur le Développement des Astéries, par M. Sars. Ann. des Sc. Nat. 1844.

(481.) The newly-laid ova consist of a chorion enclosing the vitellus and a small quantity of albumen; but the vitellus soon undergoes the usual process of segmentation, whereby it is broken up into a granular mass (fig. 91, 4, 5, 6, 7, 8). When first deposited, the ova of the Star-fishes are not at once abandoned by the parent animals, but are retained in a kind of cavity formed by incurving the body and rays of the mother until they form a sort of chamber, beneath which the eggs are protected during the earlier part of their development (fig. 91, 2). The vitellus of the ovum is entirely employed in the construction of the fœtus, which latter, at the moment of its escape from the egg, is of an ovoid or sub-spherical shape (fig. 91, 3), completely unprovided with external members, but enabled to swim vivaciously about in the surrounding water by means of the cilia with which its body is profusely covered, giving it exactly the appearance of an infusorial animalcule; indeed, this may be called the first, or infusorial condition of the young Asterias.

Fig. 91.



Development of Star-fish. 1. *Echinaster sanguinolentus* seen from below. 2. The same in profile: *a*, madreporic plate. 3. Ovarian receptacle containing ova in different states of advancement. 4, 5, 6, 7, 8. Ova exhibiting the progressive segmentation of the yelk. 9. Embryo on its first escape from the egg. 10, 11, 12. Further progress of embryo: *a a*, club-shaped processes; *b*, central protuberance. 13, 14, 15, 16, show the gradual development of the ambulatory suckers and the assumption of the radiate form.

(482.) After the lapse of a few days certain appendages begin to make their appearance, sprouting, as it were, from the anterior part of the body, and ultimately appearing as four club-shaped processes (fig. 91, 10, 11, 12, 13, *a a*) surrounding a fifth prominent protuberance, *b*, whereby the little creature fixes itself to the sides of the incubatory cavity. The body of the little Star-fish now becomes gradually flattened into a minute circular disk, upon one surface of which—hence at once distinguishable as the ventral—the rudiments of tentacula begin to be apparent, under the form of minute globular protuberances, disposed in ten concentric rows (fig. 91, 14, 15, *c c*).

(483.) If in this condition the little being is detached from the spot where it has fixed itself, it is still able to swim about in the surrounding water by means of its ciliated surface, always keeping the organs of attachment directed forwards; but if left undisturbed, it remains perfectly still and motionless, presenting what M. Sars denominates the *crinoid* state of development. At this stage, the body of the young Star-fish may still be said to be bilateral; for in all its movements the organs of attachment are directed forwards, and both sides of the body correspond exactly to each other (fig. 91, 12). But by degrees this bilateral condition is converted into the radiated form that characterizes the third, or perfect condition of the Asterias; the body gradually assumes a pentagonal outline, from the angles of which short blunt rays begin to project (fig. 91, 16); and the tentacula, now presenting the form of retractile cylinders, and completely furnished with their terminal suckers, become efficient instruments of locomotion. The red spots, regarded by Ehrenberg as the eyes, are visible at the extremities of the nascent rays; the mouth shows itself in the centre of the ventral aspect of the body; and numerous spines make their appearance. Lastly, the apparatus for attachment begins to diminish in size, and soon completely disappears, so that the young Asterias, having attained its perfect form, is ready to enter upon the duties of its station.

(484.) According to the observations of Agassiz, the eggs of the Star-fish, after they are laid, are taken up by the parent animal and kept between its tubes below the mouth. The Star-fish bends itself around them, surrounds the eggs with its suckers, and moves about with them. When the eggs have been removed to some distance from the animal, it has been observed to go towards them, take them up again, and move off with them,—showing that these creatures, so low in structure and apparently deprived of all instinct, really watch over their young. As the growth of the embryo commences, the external crust of the germ becomes more transparent, consisting of somewhat looser and larger granules, and the internal mass assumes a darker colour, so that two layers become distinct, between which a third is developed. On one side of the germ a protuberance now becomes visible, and the prominent portion separates more and more from the spherical mass, assuming by degrees the form of a peduncle. At this period there is not any organ formed—only changes of substance have taken place; but now little swellings appear in five points on the sides, and the spherical portion of the germ becomes flattened by lateral dilatation.

(485.) The minute animal has grown to a more hemispherical shape; and from this time there is an upper and a lower surface to its umbrella-like disk, and a tubular part and a swollen portion to the peduncle. As soon as the peripheric part of the disk begins to spread, five small tubercles may be observed forming underneath; and into these tubercles the peculiar aspect of the middle one extends. Soon other prominent swellings appear, two to each of the former ones, and subsequently two more. While this is going on, calcareous nets are formed by the accumulation of crystals in the cells of the germ. At first there are simply isolated crystals, formed as nuclei in the cells; then several close together will unite and form a little irregular mass; and they will at last combine, so as to constitute a network of solid substance, arranged very regularly, and gradually becoming more and more numerous, marking out more and more distinctly the rays of the embryo Star-fish. The tubercles of the lower surface, growing more prominent and elongated, are finally transformed into the suckers, or ambulacral tubes. With the addition of new calcareous nets, these latter become more numerous, and form, finally, rows of tentacles. Other changes have also taken place. The cells within the peduncle have undergone alteration: some have become moveable, and a kind of circulation is going on in them. The internal space along each ray has become more transparent; the ambulacral tubes have become hollow; and from that time there seems to be a communication between the external water and the internal structure. What remains of the yelk is more distinctly circumscribed in the centre of the animal, extending as a star-shaped disk into the rays. The radial portion becomes, finally, distinct from the central one; and we have at last an internal cavity, which is the stomach, from which the cæcal appendages of the rays, with their liver-like organ, will be developed.

(486.) The peduncle is reduced to a mere vesicle; a hole is formed in the centre of the lower surface, constituting the mouth; around this a circular thread becomes visible, answering to the nervous system, from which other threads extend towards the extremity of the rays; and by the time the young Star-fish has attained the size of about a line in diameter, it has thus assumed the form and structure of a perfect animal.

(487.) Among the most interesting contributions to our knowledge of this group are the researches of Professor Müller* relative to the embryonic condition of the *Ophiuridæ*, from which it has been ascertained that, during the progress from the egg to the mature condition, the individuals belonging to that family undergo a series of changes that are truly surprising in their character.

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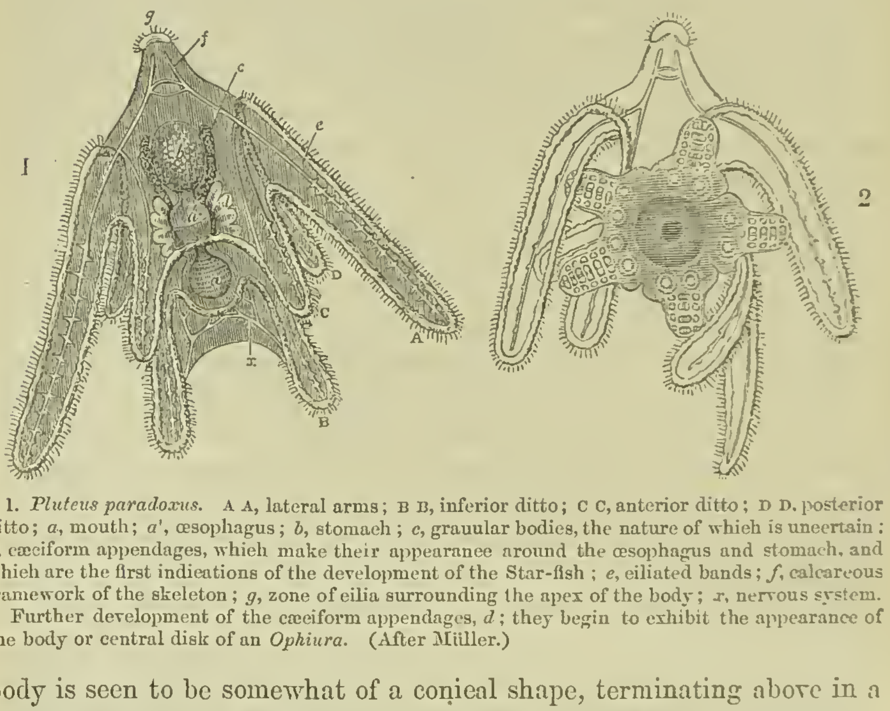
* Ueber die Larven und Metamorphose der Ophiuren und Seeigel. Berlin Trans. 1846.

(488.) The young Ophiura on leaving the egg presents itself under a most grotesque form, in which condition it has been long known to naturalists, and described under the name of *Pluteus*, or *Easel Animalcule*, from its resemblance to a painter's easel.

(489.) The *Pluteus paradoxus* (fig. 92) is exceedingly minute, being not more than $\frac{2}{5}$ths of a line in length. When highly magnified, its body is seen to be somewhat of a conical shape, terminating above in a point, but dividing inferiorly into eight long processes or appendages of various dimensions, to which it owes its peculiar figure (fig. 92, 1. A, B, C, D). Each of these processes is supported by an internal calcareous framework derived from the interior of the body (fig. 92, 1. *f*), which, branching out in different directions, forms a basis whereon the soft parts are spread out. The whole animal is perfectly transparent, its substance resembling dull glass, the apex of the body and the extremities of the arms or processes being slightly tinged with orange.

Fig. 92.



1. *Pluteus paradoxus.* A A, lateral arms; B B, inferior ditto; C C, anterior ditto; D D, posterior ditto; *a*, mouth; *a'*, œsophagus; *b*, stomach; *c*, granular bodies, the nature of which is uncertain; *d*, cæciform appendages, which make their appearance around the œsophagus and stomach, and which are the first indications of the development of the Star-fish; *e*, ciliated bands; *f*, calcareous framework of the skeleton; *g*, zone of cilia surrounding the apex of the body; *x*, nervous system. 2. Further development of the cæciform appendages, *d*; they begin to exhibit the appearance of the body or central disk of an *Ophiura*. (After Müller.)

(490.) These singularly-formed *larvæ*—for such they are—are found abundantly during the months of August and September, crowding the surface of the sea in rich profusion, swimming freely about by the aid of rows of cilia (*e*), with which their arms and the apex of their bodies (*g*) are plentifully furnished. They possess, moreover, a distinct nervous system, consisting of two little ganglia (*x*) situated just beneath the oral aperture, from whence delicate nervous threads may be traced in different directions.

(491.) The first appearance that presents itself, indicating the commencement of metamorphosis, is the development of a number of cæcal appendages around the stomach and œsophagus of the *Pluteus* (fig. 92, 1, *d*), which soon increase so much in number that they form a series of rows surrounding the stomachal cavity. At first these rows of cæca do not extend beyond the body of the Pluteus, remaining, as it were, concealed beneath its disk; but soon acquiring greater development, they make their appearance externally, and begin to assume some regularity of arrangement (fig. 92, 2), in which the rudimentary form of the star-fish begins to be perceptible, and the points whence the arms are to proceed become apparent.

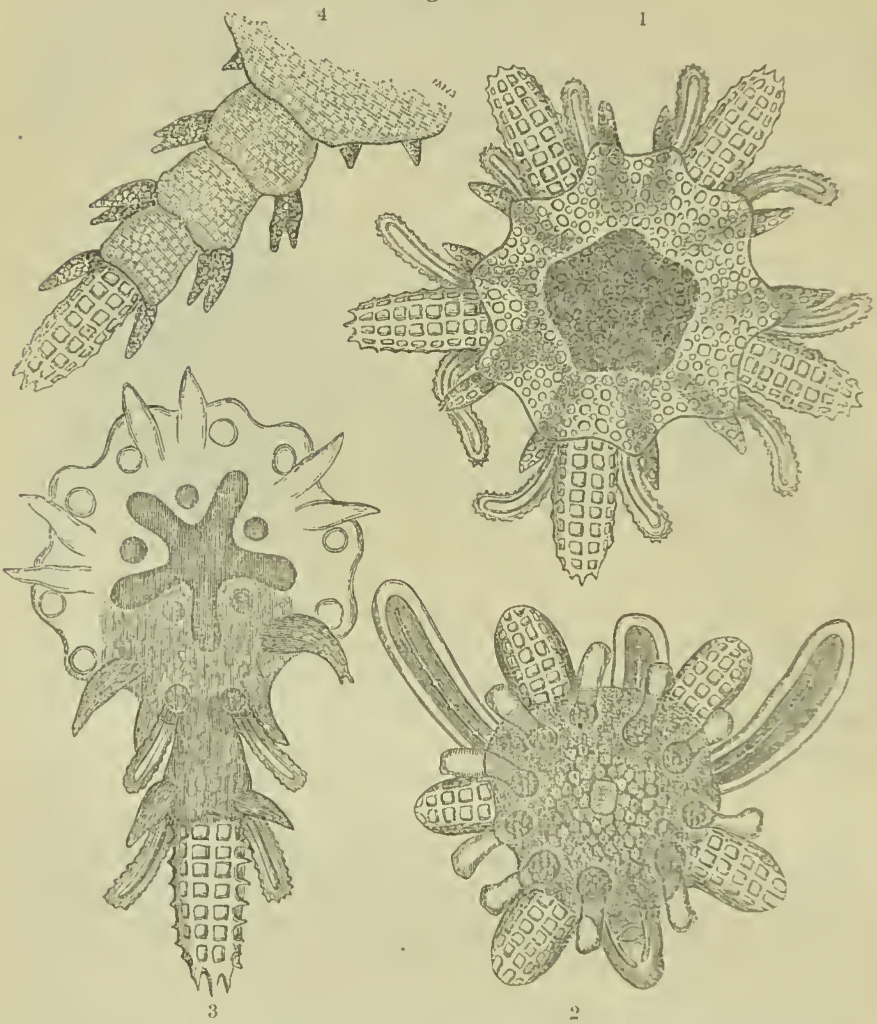
(492.) In carrying out this part of the proceeding, it will be observed that the original arms or processes of the *Pluteus* (fig. 92, 1, A, B, C, D) have had no share. The Pluteus, in fact, stands just in the same relation to the young Ophiura as the frame does to a piece of embroidery; neither has the structure of its arms anything in common with that of the rays of the future star-fish, which lies, as it were, protected beneath their shelter. As soon as the cæcal appendages have arrived at this state of development and assumed so much regularity of arrangement, calcareous earth begins to be deposited in an arborescent form, which accumulates rapidly until a kind of trellis-work is formed, spreading over the entire surface of the young Echinoderm. As the cæciform appendages thus become arranged into a regular figure, the place where the mouth of the Pluteus was becomes distorted and, as it were, forcibly pushed upwards, until it remains no longer visible, its place being occupied by the central mouth of the newly-formed star-fish (fig. 93, 2).

(493.) In the condition which it has now attained, the young star-fish is still much smaller than the rest of the Pluteus; but from this point, as its growth continues, the body and processes of the latter assume more and more the appearance of being only appendages to the newly-developed animal, until by degrees they entirely disappear, the only part of the Pluteus remaining as a part of the young Ophiura being the stomach.

(494.) Before, however, the arms of the Pluteus have entirely disappeared, the feet, or retractile suckers, have begun to show themselves, arranged in a circle around the circumference of the shield (fig. 93, 1, 2), so that it is able to creep freely about in the sea.

(495.) Shortly before the disappearance of the last remnants of the Pluteus, the arms or rays of the Ophiura are already visible, projecting prominently from the margin of the shield (fig. 93, 1, 2), but consisting as yet only of the outer or terminal joint of the future ray; the moveable spines likewise begin to show themselves, and the characters of the future Echinoderm begin to be recognizable (fig. 93, 1). Ultimately new segments begin to be added to the rays, making their appearance between the primitive segment and the margin of the disk, the original segment retaining its size and figure unaltered, while the succeeding ones differ in their shape, assuming a polygonal form, which varies in different species. The places where all new segments are formed are in the shield itself, at points situated upon the ventral aspect, between the inter-radial spaces; and each successive segment produced, being at the base of the ray, is of course larger than all that preceded it (fig. 93, 3, 4).

Fig. 93.



1. *Ophiura* in a still more advanced stage of development, showing the larva portion (Pluteus) in great part obliterated: first appearance of the mouth and tentacles. 2. The larva has entirely disappeared, and the feet and spines of the Ophiurus begin to develope themselves. 3. Shows the mode of growth of one of the rays: the terminal or primitive segment is easily recognizable, to which the following segments succeed in the order of their formation. (After Müller.)

(496.) In order to complete the history of the *Asteridæ*, we have yet to mention the nervous apparatus wherewith they are furnished. This consists of a simple circular cord that runs around the mouth of the animal; from this ring, three delicate filaments are given off opposite to each ray, one of which, according to Tiedemann, runs along the centre of the ambulacral groove upon the under surface of the body, and gives off minute twigs to the locomotive suckers placed on each side of its course; the other two filaments pass into the visceral cavity, and are probably distributed to the internal organs. There are no ganglia developed on any part of this nervous apparatus; or if, as some writers assert, ganglionic enlargements are visible at the points whence tho radiating nerves are given off, they are so extremely minute as not in any degree to merit the appellation of nervous centres.

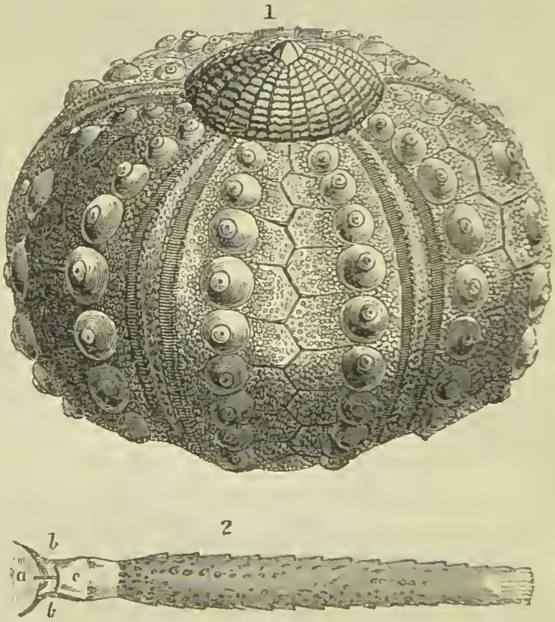
(497.) Such an arrangement can only be looked upon as serving to associate the movements performed by the various parts of the animal; for no portion of these simple nervous threads can be regarded as being peculiarly the seat of sensation or perception. Nor is this inference merely deducible from an inspection of the anatomical character of the nerves; it is based upon actual experiment. We have frequently, when examining these animals in a living state (that is when, with their feet fully developed, they were crawling upon the sides of the vessels in which they were confined), cut off with scissors successive portions of the dorsal covering of the body, so as to expose the visceral cavity; but, so far from the rest of the animal appearing to be conscious of the mutilation, not the slightest evidence of suffering was visible: the suckers placed immediately beneath the injured part were invariably retracted; but all the rest, even in the same ray, still continued their action, as though perfectly devoid of participation in any suffering caused by the injury inflicted. Such apathy would indeed seem to be a necessary consequence resulting from the deficiency of any central seat of perception whereunto sensations could be communicated. Nevertheless Ehrenberg insists upon the existence of eyes in some species of Star-fish, attributing the function of visual organs to certain minute red spots, visible at the extremity of each ray, behind each of which he describes the end of the long nerve that runs along the ambulacral groove as expanding into a minute bulb. We must confess that the proofs adduced in support of such a view of the nature of the spots appear to us to be anything but satisfactory. The general sense of touch in the Asteridæ is extremely delicate, serving not only to enable them to seize and secure prey, but even to recognize its presence at some little distance, and thus direct these animals to their food. Any person who has been in the habit of fishing with a line in the shallow bays frequented by star-fishes, and observed how frequently a bait is taken and devoured by them, will be disposed to admit this; yet, to what are we to attribute this power of perceiving external objects? It would seem most probably due to some modification of the general sensibility of the body, allowing of the perception of impressions, in some degree allied to the sense of smell in higher animals, and related in character to the kind of sensation whereby we have already seen the Actiniæ and other polyps are able to appreciate the presence of light, although absolutely deprived of visual organs.

(498.) The ECHINI, however they may appear to differ in outward form from the *Asteridæ*, will be found to present so many points of resemblance in their general structure, that the detailed account we have given above of the organization of the last-mentioned family will throw considerable light upon the still more elaborately constructed animals that now present themselves to our notice.

(499.) The *Echinidæ*, as we have already observed, differ from the star-shaped Echinodermata in the nature of the integument that encloses their visceral cavity, as well as in the more or less circular or spherical form of their bodies; so that the locomotive apparatus with which they are furnished is necessarily modified in its character and arrangement.

(500.) The shell of an Echinus (fig. 94, 1) is composed of innumerable pieces accurately joined together, so as to form a globular box enclosing the internal parts of the animal, but perforated at each extremity of its axis by two large openings, one of which represents the mouth, and the other the anus.

Fig. 94.



1. Shell of *Cidaris* denuded of its spines. 2. A spine articulated with its corresponding tubercle: *a*, section of tubercle; *b b*, capsular ligament; *c*, base of spine.

(501.) The calcareous plates entering into the composition of this extraordinary shell may be divided into two distinct sets, differing materially in shape, as well as in the uses to which they are subservient. The larger pieces are recognizable in the figure by hemispherical tubercles of considerable size attached to their external surface, adapted, as we shall afterwards see, to articulate with the moveable locomotive spines. Each of these larger plates has somewhat of a pentagonal form,—those that are situated in the neighbourhood of the mouth and anal aperture being considerably the smallest, and every succeeding plate becoming progressively larger as they approximate the central portion of the shell: the entire series of pieces in each row resembles in figure the shape of the space included between two of the lines marking the degrees of longitude on a terrestrial globe—broad at the equator, but gradually narrowing as it approaches the poles,—an arrangement, of course, rendered necessary by the spherical form of the creature. There are ten rows of these tuberculated plates; but as they are disposed in pairs, each row of large pieces being united by a zigzag suture with another of a similar description, there are in reality only five large segments of the shell, each supporting a double row of tubercles.

(502.) The reader must not, however, conclude that the great central tubercles above mentioned are the only parts of the shell to which spines are affixed; hundreds of smaller elevations are disseminated over the surface, whereunto smaller spicula are appended—although, from their diminutive size, these are of secondary importance in locomotion.

(503.) The five large double segments that thus form the greater portion of the calcareous shell are separated from each other by the interposition of ten rows of perforated plates, likewise disposed in pairs, and composed of much smaller pieces than those which support the tubercles; hundreds of foramina, piercing these ambulacral bands, give passage to as many tubular feet or protrusible suckers, in every respect resembling those of *Asterias*, and distended by a similar apparatus.

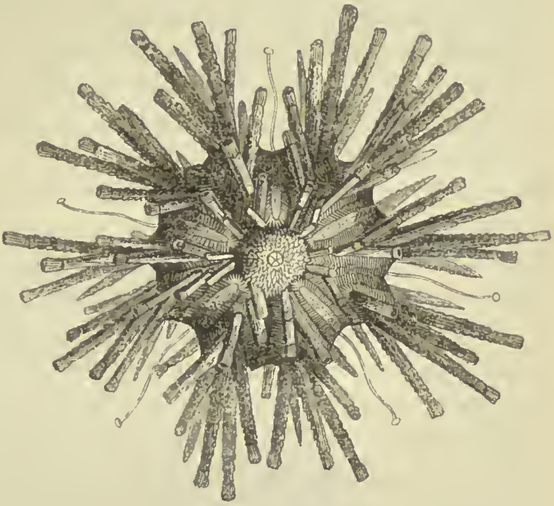
(504.) It is impossible, by any verbal description at all commensurate with the limits of our present undertaking, adequately to explain the more minute contrivances visible in the disposition of every portion of these wonderfully-constructed coverings: it is sufficient for our present purpose to observe that the globular crust of an Echinus is made up of several hundred polygonal pieces, of different sizes, and, although presenting every variety of outline, generally approximating more or less to a pentagonal form; that these pieces are so accurately and completely fitted to each other, that the lines uniting them are scarcely to be distinguished, even upon the most minute examination; and that from the union of so many distinct and dissimilar plates results a firm, compact, and beautiful box, similar to that represented in the figure. The first question that naturally suggests itself, on examining a shell of this description, is concerning the object to be attained by such remarkable complexity; it would appear, indeed, at first sight, that a simple calcareous crust, had it been allowed to exude from the entire surface of the Echinus, would gradually have moulded itself upon the body of the creature, and thus have formed a globular shell without suture, answering every purpose connected either with support or defence.

(505.) A very little investigation, however, will suffice to show the necessity for the elaborate arrangement to which we have alluded. In the first place, as we shall immediately see, the earthy matter is not deposited upon the surface of the body, but within the soft external integument whereby it is secreted,—the interior of the shell being filled with sea-water, in which the viscera are loosely suspended. But a second and more important reason for the employment of so many pieces in the construction of the shell of an Echinus is to be derived from examining the mode in which the animal grows. Were it to retain the same dimensions throughout the whole period of its life, or could it, at stated intervals, cast off its old investment and secrete a new and more capacious covering as growth rendered the change necessary, a simple earthy crust would have been sufficient, without the presence of such an immense number of sutures and joinings. The calcareous plates of the Echinus, it must be remembered, are merely secreted from the soft parts, having no vital action going on within them whereby, as in the bones forming the skeletons of vertebrate animals, a continual deposition of fresh particles could be effected, allowing of extension by interstitial deposit. How, therefore, could the growth of the Echinus be provided for? How is the gradual expansion of the entire shell, thus composed of a dense and extravascular crust, to be effected—and that without ever deranging the proportions of the whole fabric, or necessitating a loosening of its parts? No other contrivance could apparently have been adequate to the purpose: nevertheless we see how admirably, by the structure adopted, the growth of these creatures proceeds in all directions; for the living and vascular membrane that covers the whole external surface of the body dips down between the edges of the various calcareous pieces, and continually deposits, around the margin of each, successive layers of earthy particles, which, assuming a semi-crystalline arrangement, progressively increase the dimensions of each individual plate. But the continual augmentation in size which is thus going on is attended with no change in the mathematical figure of any given piece of the skeleton; so that, as they still increase in diameter by the unceasing deposition of earthy matter around the circumference of every plate, the spherical shell gradually expands, without in any degree altering its form or relative proportions, until it has acquired the mature dimensions belonging to its species.

(506.) The tubular suckers or retractile feet, that are protruded at the pleasure of the animal from the countless minute apertures seen in the ten rows of ambulacral plates, are so similar in all essential points to those of *Asterias* already described, that little further need be said concerning their structure, or the mechanism whereby their motions are effected. The tubular part of each foot communicates with the interior of the shell by two branches passing through two apertures: and these branches, in some species (as *Echinus saxatilis*), receive offsets from the vessels that run along the centre of each ambulacral groove, and convey to the feet the fluid by which their distention is effected. In *Echinus esculentus* the feet open into a plexus of vessels, formed in leaf-like membranes, equal in number with the feet, and disposed in double rows upon the inner surface of the ambulacral pieces*, by the intervention of which they are connected with the canals above mentioned.

(507.) The tubercles upon the external surface of the shell of the *Echini* support a corresponding number of long spines, which, as well as the apparatus of suckers, are employed as locomotive agents. These spines vary materially in their form and proportionate size, and even in their internal structure and mode of growth, as may be readily seen by a comparison of different species. Thus, in the flattened forms of *Scutellæ* and allied genera, they are so minute as to require the employment of a microscope for their investigation; in *Echinus esculentus* (fig. 85) they are sharp, and almost of equal length over the entire surface of the animal; while in the specimen represented in the annexed figure (fig. 95), the shell of which we have already examined when divested of these appendages, the length of the spines that are articulated upon the large tubercular plates fully equals the transverse diameter of the body of the creature, and in some cases they are even found much more largely developed. Every spine, examined separately, is seen to be united with the tubercle upon which it is placed by an apparatus of muscular and ligamentous bands, forming a kind of ball-and-socket joint, allowing of a considerable extent of motion. The structure of this articulation is exhibited in fig. 94, 2. The large tubercle (a) supports upon its apex a smaller rounded and polished eminence, perforated in the centre by a deep depression; and the bottom of the moveable spine (c) is terminated by a smooth hemispherical cavity accurately fitted to the projecting tubercle, so that the two form complete articular surfaces. The bonds of union connecting the spine with the shell are of two kinds: in the first place, there is a stout ligament (a, c), extending from the little pit seen upon the centre of the tubercle, to a corresponding depression visible upon the articular surface of the spine, resembling very accurately the round ligament found in the hip-joint, and obviously a provision for the prevention of dislocation.

Fig. 95.



Cidaris.

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* Cyclopædia of Anat. and Phys., art. "ECHINODERMATA."

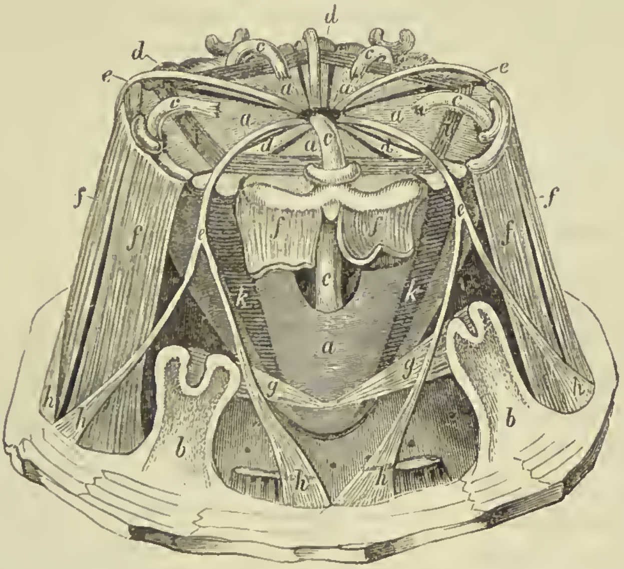
(508.) Moreover, the whole joint is enclosed in a muscular capsule, composed of longitudinal fibres (*b b*) arising from the circumference of each tubercle, and inserted all around the root of the spine: these fibres, therefore, which must, in fact, be regarded as merely derived from the general irritable skin that clothes the shell externally, are the agents which, acting immediately on the spine, produce all the movements whereof it is capable.

(509.) The next thing to be accounted for in the history of these elaborately-constructed animals is the growth of the spines themselves: these, as we have already seen, are completely detached from the rest of the shell, to which they are secured only by the central ligament and by the muscular capsule enclosing their base. To account, therefore, for the production of organs so completely insulated as the spines appear to be, especially when we consider that there is no vascular communication between them and the body of the Echinus, would appear to be a matter of some difficulty; and in fact, had we not already seen, in the Polyps, the amazing facility with which calcareous matter was secreted by the living textures of those animals, it would be almost impossible to conceive by what process their growth was effected. On examining one of these appendages, taken from a species wherein they are largely developed, when fresh, before its parts have become dry, every portion of its surface is seen to be invested with a thin coat of soft membrane, derived from that which covers and secretes the whole shell, whereof indeed the muscular capsule enclosing its articulation with the tubercle is only a thickened portion.

(510.) The living covering of the spine, therefore, like the crust that invests the cortical Polyps, is the secreting organ provided for its growth, depositing the earthy particles separated from the waters of the ocean, layer after layer, upon its outer surface, so as to form a succession of concentric laminæ, of which the outer one is always the last formed. The calcareous matter thus deposited has, more or less completely, a crystallized appearance; and on a transverse section of the organ being made, and the surface polished by grinding, the whole process of its formation is at once rendered evident. Such sections, indeed, form extremely beautiful and interesting subjects for microscopical examination, as nothing can exceed the minute accuracy and mathematical precision with which each particle of every layer composing them appears to have been deposited in its proper place: in fact, if the zootomist would fully appreciate the minuter details connected with their organization, it is only by the employment of the microscope that he will arrive at adequate ideas concerning them; for it is not in the number and variety of the pieces entering into the composition of the skeleton of one of these animals, the extraordinary apparatus of prehensile suckers with which they are furnished, or the singular locomotive spines upon the exterior of the shell, that he will find the most remarkable features of the history of the Echini; it is only by a minute examination of the intimate structure of each of these parts that the perfection of the mechanism conspicuous throughout can be properly understood.

(511.) The calcareous pieces surrounding the mouth of the *Echinus* are not so immoveably consolidated as those composing the rest of the shell, but, on the contrary, admit of considerable movement, whereby the prehension of food is materially facilitated. The mouth itself (fig. 94, 1) is a simple orifice, through which the points of five sharp teeth are seen to protrude. These teeth obviously perform the office of incisors, and from their sharpness and extreme density are well calculated to break the hard substances usually employed as food. The points of such incisor teeth, although of enamel-like hardness, would nevertheless be speedily worn away by the constant attrition to which they are necessarily subjected, were there not some provision made to ensure their perpetual renewal; like the incisor teeth of rodent quadrupeds, they are therefore continually growing, and are thus always preserved sharp and fit for use. In order to allow of such an arrangement, as well as to provide for the movements of the teeth, jaws are provided, that are situated in the interior of the shell; and these jaws, from their great complexity and unique structure, form, perhaps, the most admirable masticating apparatus met with in the whole animal kingdom; we must therefore entreat the patience of the student while we describe at some length the parts connected therewith. The entire apparatus

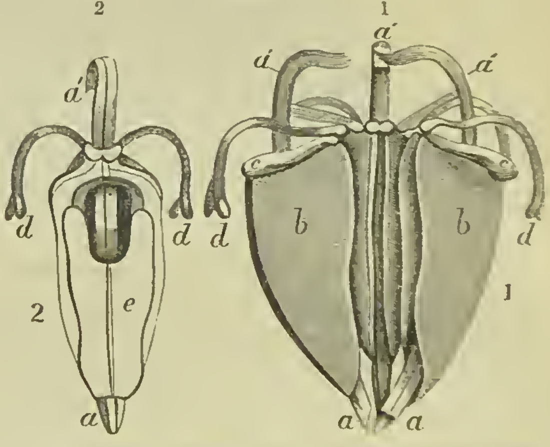
Fig. 96.



Oral apparatus of Echinus: *a a a a a*, pyramidal pieces forming the "lantern of Aristotle"; *b b*, internal projections from shell; *c c c c c*, teeth enclosed in their sockets; *d d*, interposed osseous pieces; *e e*, curved processes; *f f*, *g g*, *h h*, *i i*, *k k*, muscular fasciculi for the movements of the jaws.

removed from the shell is represented in fig. 96, and consists of the following parts:—There are five long teeth (*c c*), each of which is enclosed in a triangular osseous piece (*a a*), that for the sake of brevity we will call the jaws. The five jaws are united to each other by various muscles (*k k*, *i i*), so as to form a pentagonal pyramid, having its apex in contact with the oral orifice of the shell, while its base is connected with several bony levers by means of numerous muscles provided for the movements of the whole. These parts we must now proceed to describe *seriatim.* The teeth (fig. 97, 1, *a*) resemble, at the part protruded from the mouth, long three-sided prisms, and at this point they are extremely hard and brittle: each tooth is fixed in a socket passing through the jaw (fig. 97, 2, *e*), from which it projects by its opposite extremity (fig. 97, 2, *a'*), that may be called the root of the tooth, where, instead of being of glassy hardness like the point (*a*) which issues from the mouth, it is flexible and soft, resembling fibres of asbestos, and is covered by a membrane apparently connected with its secretion. The jaws, which thus support and partially enclose these teeth, are five in number: when examined separately, each is found to resemble in figure a triangular pyramid, the external surface (fig. 97, 2. *e*) being smooth, and presenting eminences provided for the attachment of muscles; while the other two sides (fig. 97, 1, *b b*) are flat, and marked with transverse grooves, so as to have the appearance of a fine file. When the five jaws are fixed together in their natural positions, they form a five-sided conical mass, aptly enough compared by Aristotle to a lantern, and frequently described by modern writers under the name of the "lantern of Aristotle." When thus fitted to each other, the two flat and striated sides of each jaw are in apposition with the corresponding surfaces of two others, so that there are ten grinding surfaces formed, between which the food must pass preparatory to its introduction into the digestive canal. This arrangement will be easily understood by referring to fig. 97, 1, in which three of these jaws, each containing its incisor tooth, are represented *in situ.*

Fig. 97.



Dental system of Echinus. 1. Represents three of the pyramidal pieces forming the "lantern of Aristotle" *in situ*: *a a*, cutting extremities of the incisor teeth, which are of enamel-like hardness; *a' a' a'*, fibrous roots of the same, resembling asbestos in their texture; *b b*, opposed flat surfaces of the jaws; *d d*, arched processes. 2. An isolated pyramid: *e*, its external surface. Other letters as in fig. 1.

(512.) The five curious jaws described above are fixed together by a set of muscles (fig. 96, *k k*), consisting of short fibres passing between the external edges of the contiguous segments of the lantern, and evidently capable of powerfully approximating the grinding surfaces and rubbing them upon each other. The jaws, moreover, are provided with five other osseous pieces (*d d*), arranged in a radiating manner between the bases of the different segments, with which they are connected by ligaments, and likewise by the pentagonal muscle (*i i*) that runs from one to the other.

(513.) The above-described parts complete the apparatus required for connecting the different portions of this remarkable mouth; but the movements of the whole are effected by a very complicated set of levers and muscles, which must next be noticed.

(514.) The levers attached to the jaws are five long and slender processes (fig. 97, 1, *d d*), each arising from the central extremity of one of the radiating osseous pieces (*c c*), and arching outwards considerably beyond the base of the lantern, to terminate by a forked extremity. But there are likewise other processes projecting from the inner surface of the shell; these, two of which are seen in fig. 96, *b b*, are also five in number, and are placed around the orifice of the mouth: they are generally perforated in the centre, so as to resemble so many bony arches; and from them, as well as from the spaces which separate them, numerous muscles derive their origin. Of these muscles, ten (*f f*) arise from the spaces between the arches, two being inserted into the outer edge of the base of each jaw; so that the effect produced by their contraction, when they all act in concert, will be to approximate the whole mass of the mouth to the oral aperture of the shell, and of course cause the points of the incisor teeth to protrude externally; or, if they act separately, they can draw the base of the lantern in any direction, or cause the grinding surfaces of the jaws to work against each other.

(515.) The antagonists to the muscles last mentioned are ten others (*g g*), arising from the extremities of the arches themselves, and running in a radiating manner towards the apex of the lantern, so that the point of each piece or jaw receives a muscle from two of those processes. These fasciculi, from the manner in which the arches project into the cavity of the shell, will draw inwards the entire mass; or, if they act separately upon the jaws whereunto they are individually fixed, they will produce movements precisely opposite to those caused by the contractions of the muscles derived from the spaces between the bony processes; or, if both sets should act in concert, they become the antagonists of the muscles (*i i*, *k k*) that connect the jaws to each other, and by causing the separation of the different pieces they necessarily enlarge not only the opening of the mouth, but all the passage leading to the œsophagus through the axis of the lantern.

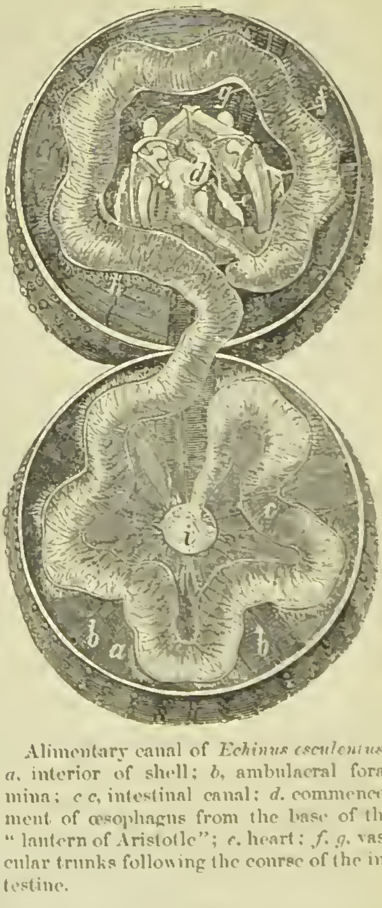
(516.) Yet even these are not all the muscles that act upon the masticating apparatus: ten others (*h h*), arising in pairs from the middle of the interspaces between the arches, are connected with the bifurcated extremities of the slender curved processes (*e e*), each of these receiving a muscle from two contiguous spaces; and, from the length of the levers upon which these muscles act, we may well conceive the force wherewith they will influence the motions of the whole mass of the jaws.

(517.) Such is the complex structure of the mouth of *Echinus esculentus*—a piece of mechanism not less remarkable on account of the singularity of its construction, than as exhibiting an example of the sudden development of a dental system, whereof not a vestige is visible in any of the preceding Echinoderm families. In others of the Echinidæ having the shell much depressed, the dental lantern is modified in form and proportionately flattened, but the different parts are essentially similar to those we have described.

(518.) The œsophagus (fig. 98, *d*) is continued from the termination of the central canal that traverses the axis of the lantern, and, after a short course, terminates in a much wider portion of the digestive tube, into which it opens on the lateral part of its cæcal origin, in a manner precisely resembling the communication between the large and small intestines of man.

(519.) The dilated alimentary tube (*c*) presents no separation into stomach and intestine, but is continued in a winding course around the interior of the shell, which it twice encircles, and, becoming slightly constricted, terminates at the anal orifice (*i*). The walls of the intestine are extremely delicate, although they may be distinctly seen to contain muscular fibres and are covered with innumerable vascular ramifications. The external tunic of the whole canal is derived from the peritoneum, that lines the entire shell, invests the dental lantern, and forms sundry mesenteric folds as it is reflected upon the other viscera.

Fig. 98.



Alimentary canal of *Echinus esculentus*: *a*, interior of shell; *b*, ambulacral foramina; *c c*, intestinal canal; *d*. commencement of œsophagus from the base of the "lantern of Aristotle"; *e*. heart; *f*. *g*. vascular trunks following the course of the intestine.

(520.) The system of vessels provided for the circulation of the blood has been differently described by different authors—a circumstance by no means surprising when we consider the great difficulty of tracing such delicate and extensively-distributed canals. According to Delle Chiaje, the course of the nutritious fluid is as follows:—A large vein runs along the whole length of the intestine, from the anus to the œsophagus, where it terminates in a vascular ring surrounding the mouth,—into which, as in *Asterias,* the contractile vesicle, which he considers to be a receptacle for the nutrient fluid, and the antagonist to the tubular feet, likewise opens. The intestinal vein he regards as the great agent in absorbing nourishment from the intestine and conveying it to the vascular circle around the œsophagus, from which the arteries are given off to supply the whole body. These arteries are, 1st, a long vessel to the intestine, which runs along its whole length and anastomoses freely with the branches of the intestinal vein; 2ndly, five arteries to the parts connected with the mouth; 3rdly, five dorsal arteries that run along the interior of the shell between the ambulacral rows as far as the anal orifice, at which point each dorsal artery leaves the osseous box through an aperture specially provided for its exit, and, arriving upon the outer surface of the shell, supplies the soft external membrane, and in some species may be traced back again between the rows of ambulacral suckers as far as the mouth. These dorsal arteries, like the corresponding vessels in *Asterias,* supply the vascular origins of the innumerable protractile feet.

(521.) The chylaqueous system of the Echinidæ, comprehending a considerable mass of fluid filling the cavity of the spherical shell, has been generally regarded as sea-water poured into the visceral cavity through perforations in certain membranous processes of the shell, which have received the name of *branchiæ,* and are distributed in groups around the circumference of the oral membranous disk. The latter, however, according to Dr. Williams, are not connected with the suctorial or water-vascular system, but are distended by injections thrown into the open chamber of the shell, being protruded only by the force of the fluid driven into their interior; they are consequently not perforated.

(522.) In addition to the meridional rows of suctorial feet, the shell of *Echinus* is perforated by numerous hollow membranous processes lined within and without by vibratile cilia, and penetrated exclusively by the fluid of the visceral cavity; they show no traces of blood-vessels, and can only subserve a respiratory purpose on the supposition that the subject of that process is the chylaqueous fluid. There is, therefore, no direct evidence to show that the external element enters through openings in the integuments into the peritoneal cavity of the Echinus.

(523.) Nevertheless, besides this diffused respiration, Delle Chiaje regards a series of pinnated tentacula in the neighbourhood of the mouth as being in some degree capable of performing the office of branchiæ. These organs, which are protruded through a row of distinct orifices placed around the oral aperture of the shell, are eminently vascular;

and as they present a large surface to the action of the water and receive numerous vessels from the circular trunk that surrounds the mouth, they may, no doubt, very well contribute to the complete exposure of the blood to the influence of the surrounding medium.

(524.) Little is known concerning the nervous system of the *Echini*: a few delicate filaments have been observed in the neighbourhood of the œsophagus, apparently of a nervous character, communicating with a nervous ring placed in that vicinity, resembling that already described in *Asterias*.

(525.) The *Echini*, like the Star-fishes, are bisexual, and in the structure of their reproductive organs display, if possible, greater simplicity than even the Asteridæ above described. The ovaria are five delicate membranous bags, quite distinct from each other, that open externally by as many delicate tubes, or oviducts, as we may term them. The apertures through which the eggs escape are easily seen upon the outer surface of the shell, placed around the anus, and are recognizable not merely by their size, but from the circumstance of each perforation being placed in the middle of a distinct oval plate of the shell, distinguished by zoological writers as the ovarian pieces. The membranous sacs in which the ova are secreted vary in size in proportion to the maturity of the eggs contained within them, and at certain times of the year are enormously distended: it is in this state that the "roe of the Sea-egg," as the ovaria are commonly called, is used as an article of food; and in some countries, especially upon the shores of the Mediterranean, they are eagerly sought after, when in season, by divers employed to procure them. The corresponding organs in the male sex are only distinguishable by the spermatozoa contained in their interior instead of ova.

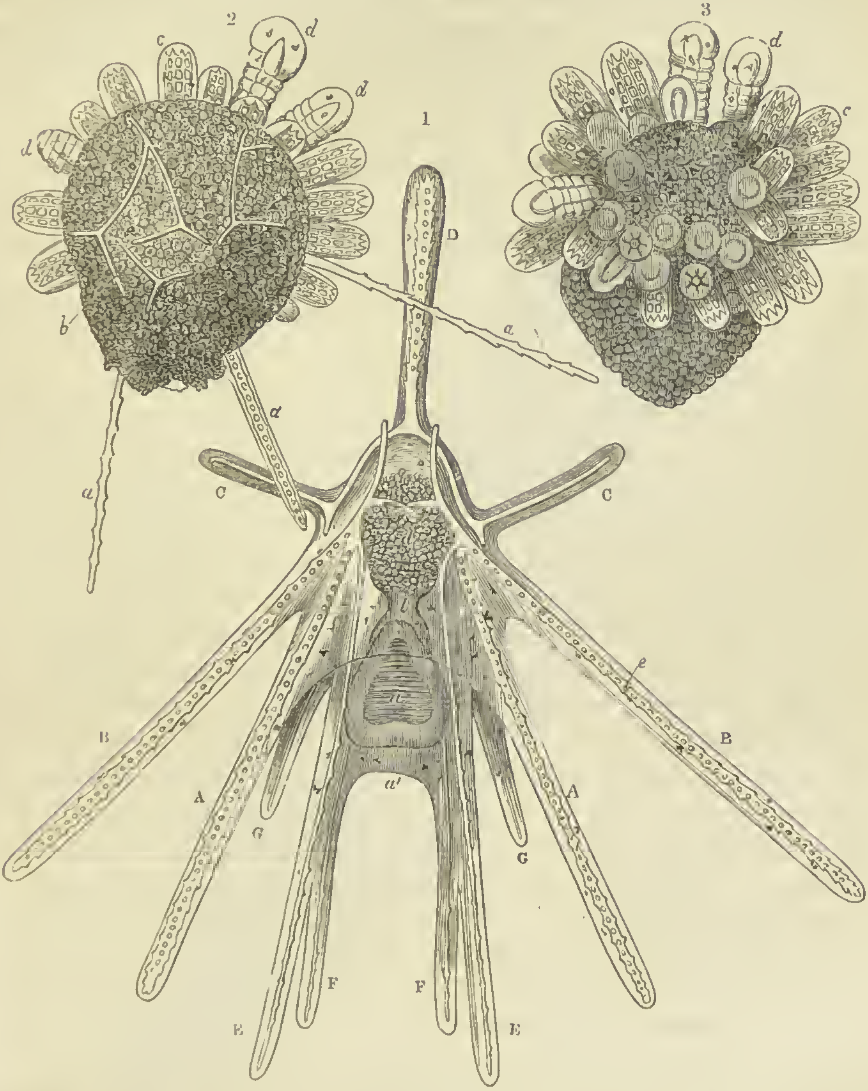
(526.) At the earliest period observed by Müller, the larval Echinus (fig. 99, 1) had the appearance of a transparent dome-like disk, hollowed out inferiorly, and having its margin prolonged into long, slender, diverging processes supported on calcareous pieces deposited in their substance, and giving the whole animal somewhat the appearance of a timepiece standing on many legs (A, B, F, E), four of which (F, E) constitute a sort of framework surrounding the oral apparatus.

(527.) The arrangement of the locomotive apparatus of these larvæ is very peculiar, consisting of four epaulet-like wreaths of long cilia situated upon the dome-shaped body of the animal, and of numerous ciliated fringes spread over the arms and in the vicinity of the oral organs.

(528.) The mouth is a triangular orifice (fig. 99, 1, *a*) furnished with broad lips, and leads immediately into the stomach (*d*), which is a *cul-de-sac*, situated in the interior of the body.

(529.) In this condition the larvæ are not more than half a line in length, and move freely about in the water, rowed along by the action of their cilia, while the marginal processes and other appendages to the body remain quite passive and motionless. The first appearance of metamorphosis is indicated by the development of a shield-like plate (fig. 99, 2, *b*), which, during the months of August and September,

Fig. 99.



Metamorphosis of Echinus. 1. A *Pluteus* with thirteen arms: A A, anterior inferior lateral processes; B B, posterior inferior processes; C C, lateral processes of the vaulted disk; D, terminal process from the apex of the vaulted disk; E E, anterior, and F F, posterior processes of the framework of the mouth; G G, posterior processes of the body: *a*, mouth; *a'*, basin-like underlip; *l*, œsophagus; *d*, stomach; *e*, calcareous framework of the skeleton. 2. The same in a more advanced stage of development—the spines of the young Echinus beginning to make their appearance, covered with a transparent skin: *a*, remnant of the calcareous skeleton of the larva or *Pluteus*, which has now nearly disappeared; *b*, branched calcareous spicula belonging to the larva skeleton; *c*, spines, and *d*, tentacles of the young Echinus. 3. The echiniform condition almost completed, only a few calcareous spicula of the larva remaining. (After Müller.)

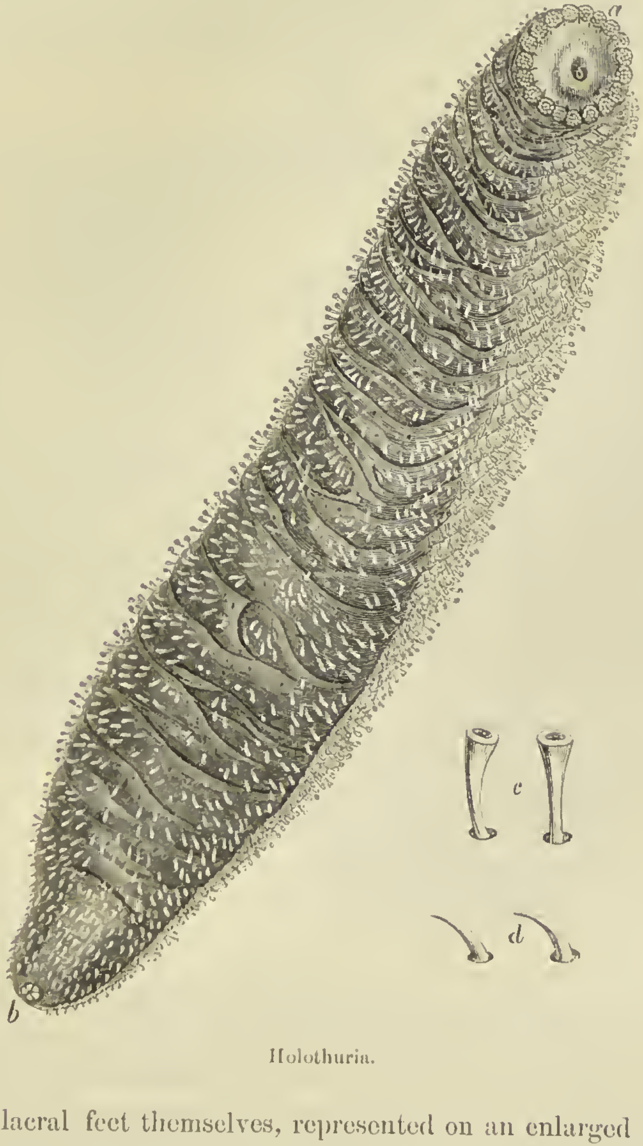
becomes visible beneath the skin covering the dome of the body, sloping as if inclined towards its apex, and not inaptly representing the finger-plate of the timepiece to which, as to its shape, the creature has been already compared. The round shield-like plate thus formed is divided by a cinquefoil-shaped figure into five compartments, and constitutes the first rudiment of the future Echinus; as its size increases, new divisions make their appearance upon its periphery, indicating the situations of the future tentacles or feet; and soon afterwards little round tubercles begin to develope themselves, which gradually rise up into cylindrical elevations and ultimately assume the appearance and texture of the locomotive spines.

(530.) The shield itself, forming the basis upon which the apparatus of suckers and spines is supported, is now seen to enclose in its substance its own proper calcareous skeleton: this consists at first of minute detached triradiate spicula, which, as they increase in number, arrange themselves so as to constitute a sort of network in the texture of the skin, wherein ultimately the polygonal calcareous plates of the shell make their appearance.

(531.) Holothuridæ.—The name applied by naturalists to the animals composing the next family of Echinodermata is derived from a Greek word of uncertain application (ὁλοθούριον). In common language they are generally known by the appellation of "Sea-cucumbers"; and in fact, to a casual observer, the resemblance which they bear to those productions of the vegetable kingdom, both in shape and general appearance, is sufficiently striking. The surface of these animals is kept moist by a mucus that continually exudes through innumerable pores and appears to be secreted by minute follicles imbedded in the substance of the skin. The integument which covers, or, rather, forms the body, is entirely destitute of those calcareous pieces that encase the Echini and Star-fishes; it appears to consist of a dense fibrous cutis of considerable thickness, covered externally with a thin epidermic layer. Beneath the cutis is another tunic, composed of strata of tendinous fibres crossing each other in the midst of a tissue of a semicartilaginous nature, which is capable of very great distention and contraction. and serves by its elasticity to retain the shape of the body. Within this dense covering are seen muscular bands running in different directions. which by their contraction give rise to the various movements of the creature: of these muscles five strong fasciculi assume a longitudinal course, passing along the entire length of the animal from the mouth to the cloaca; and in the interspaces between these, circular and oblique muscles are readily distinguishable. The whole of this muscular case is lined with a delicate membrane or peritoneum, from which processes pass inwards to support the various viscera.

(532.) But although the calcareous shell of the Echinus is thus totally lost, the locomotive suckers or feet already described are still the principal agents employed in progression. In many species, as in that represented in the annexed figure (fig. 100), these organs are distributed over the whole surface of the animal, and are protruded through countless minute orifices that perforate the integument. In other cases, as in *H. frondosa*, they are arranged in five series, resembling the ambulacra of an Echinus; and in some instances they are only found upon the middle of the ventral surface of the body, that forms a flattened disk upon which the animal creeps, somewhat in the manner of a snail.

Fig. 100.



Holothuria.

The ambulacral feet themselves, represented on an enlarged scale at *c*, precisely resemble in all the details of their structure those of the Asterias, and their protrusion and retraction are effected in the same manner; but, in addition to these organs, we find in some genera moveable hooks or spines (fig. 100, *d*), which are likewise retractile, and most probably assist in locomotion.

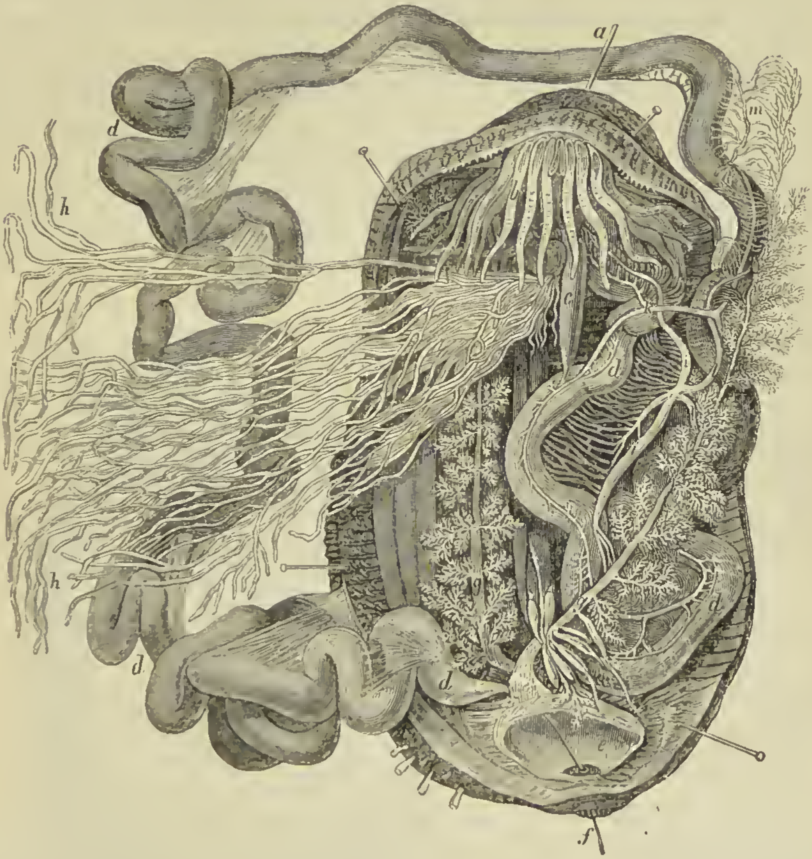
(533.) The mouth is a round aperture, as wide as the bore of a goose-quill, placed in the centre of a raised ring at the anterior extremity of the body (fig. 100, *a*). Around the oral orifice is placed a circle of tentacula, which are apparently extremely sensitive, and serve perhaps not only as instruments of touch, but as prehensile organs, used for the capture of prey, or for assisting in deglutition. When the sphincter muscle that closes the mouth contracts, the tentacles are withdrawn, and become no longer visible externally; in this state, on opening the animal (fig. 101, *b*), they are found to resemble long cæca appended to the commencement of the œsophagus, and have been described by some authors as forming a salivary apparatus.

(534.) The total deficiency of an external skeleton or calcareous framework precludes, of course, the possibility of the existence of any complex dental apparatus resembling the "lantern of Aristotle;" the only vestige of the complex teeth of the Echinidæ which here remains is a small circle of calcareous pieces, surrounding the opening of the mouth. These plates, from their extreme friability, have been aptly enough likened to laminæ of dried paste: they may indeed, in some slight degree, be efficient in bruising food taken into the mouth; but it is more probable that they merely form points of insertion for the longitudinal muscles of the body, which, thus fixed around the circumference of the oral orifice, will by their contraction powerfully dilate that aperture for the purpose of taking in nourishment.

(535.) The alimentary canal is of great length, but, like that of the Echinus, presents no stomachal dilatation; from the mouth (fig. 101, *a*), in which a bristle is placed, it descends to the anal extremity of the body, where, turning upon itself, it again mounts up towards its commencement, whence turning back again, and forming numerous convolutions (*d d d*), it once more passes backwards, and becoming constricted near its termination, opens into a large membranous cavity (*e*) that may be called the cloaca. Throughout the whole of this long course, the alimentary tube is surrounded with a membrane derived from the peritoneal lining of the visceral cavity, which forms delicate mesenteric folds connecting it to the walls of the body and supporting it through its entire length. The whole intestine is generally found distended with sand, wherein may be detected the débris of corals, algæ, fuci, and other marine substances.

(536.) In the structure of the respiratory apparatus, the Holothuridæ differ materially from the rest of the Echinodermata, and, in fact, from all other animals. In the Holothuria, the aëration of the circulating fluid is provided for by allowing the surrounding element freely to enter into the internal parts of the creature; but instead of bathing the surfaces of the viscera, the water is confined in a peculiar system of ramifying canals, forming a structure of great beauty and, from its singularity, extremely interesting in a physiological point of view. We have seen that the intestinal canal terminates in a membranous receptacle or cloaca (fig. 101, *e*), contained within the cavity of the abdomen, to the walls whereof it is attached by delicate fleshy bands: this cloacal cavity communicates with the exterior of the body by a wide orifice twice as large as the aperture of the mouth, through which, in the figure, a bristle (*f*) has been passed; and it is by this orifice that the water required for the purpose of respiration is taken in, and then forced, by the muscular walls of the cloaca itself, through the whole system of respiratory canals whereby its distribution is effected. The organs of respiration commence at the upper part of the cloaca, near the termination of the intestine, by a large opening leading to a wide membranous tube, which immediately divides into two vessels (*g g*) forming the main trunks of the beautiful arborescent branchiæ; these extend to the opposite extremity of the body, giving off in their course numerous lateral branches that divide and subdivide, so as to form what has been not inaptly termed the "respiratory tree," until they ultimately terminate

Fig. 101.



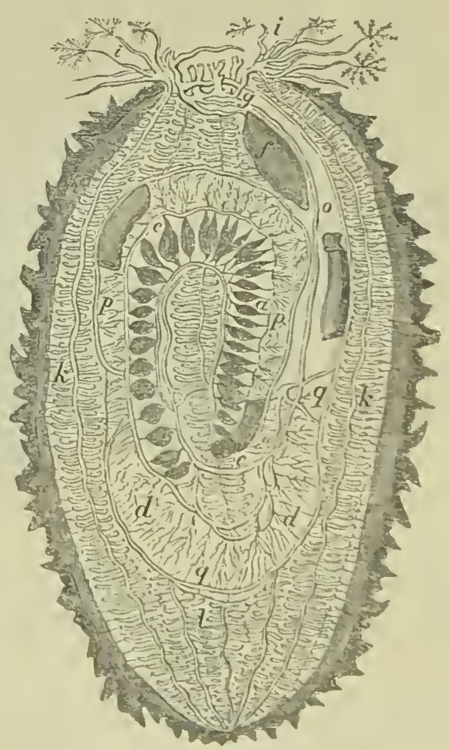
Anatomy of *Holothuria*: *a*, bristle inserted into the mouth; *b*, inverted tentacula; *c*, ampulla Poliana; *d d d*, intestinal canal; *e*, cloacal chamber opening externally by a wide orifice, into which the bristle, *f*, has been passed; *g g*, "respiratory tree;" *h h*, ovarium (testis in the male); *i i*, central vascular trunk; *k*, intestinal vessel; *l*, *m*, vessels in relation with the "respiratory tree."

in minute vesicular cæca, into which the water derived from the cloaca of course penetrates. One division of this elegant apparatus is maintained in close contact with the walls of the body by a series of delicate tendinous bands, while the other becomes applied to the convolutions of the intestines, wherewith it is likewise united. It is this last-mentioned division that would appear to be specially provided for the oxygenization of the nutritive fluids.

(537.) The circulation of the blood in the Holothuria, as in the Echinus, is still but imperfectly understood; and considerable difference of opinion upon this subject will be found in the writings of anatomists. According to Tiedemann*, innumerable small veins collect the blood and nutritive products of digestion from the intestine and convey them into a large central vessel (fig. 101, *i i*), from whence the circulating fluid passes by other trunks (*l l*) to the respiratory tree; hence it is returned by vessels (partly represented at *m*) to the intestinal artery (*k*), by which it is again distributed over the intestinal parietes.

(538.) Delle Chiaje gives a different account of the arrangement of the vascular system in these creatures, which he seems to have investigated with his usual untiring perseverance. According to the last-mentioned anatomist, the blood is taken up from the intestines by a complicated system of veins, the main trunks of which are indicated in the annexed diagram (fig. 102) by the letters *c*, *e*, *p p*, *q q*; these communicate with each other not only by the intervention of numerous anastomosing branches (*d d*), but likewise by means of delicate vascular plexuses (*a*) passing between them. All these veins terminate in two large venous canals (*o*) that convey the blood and nutriment absorbed from the intestine to a vascular circle (*g*) placed around the commencement of the œsophagus, which corresponds with the circular vessel around the mouth of the Echinus. This circle Delle Chiaje regards as the centre

Fig. 102.



Plan of the circulation in *Holothuria*, according to Delle Chiaje.

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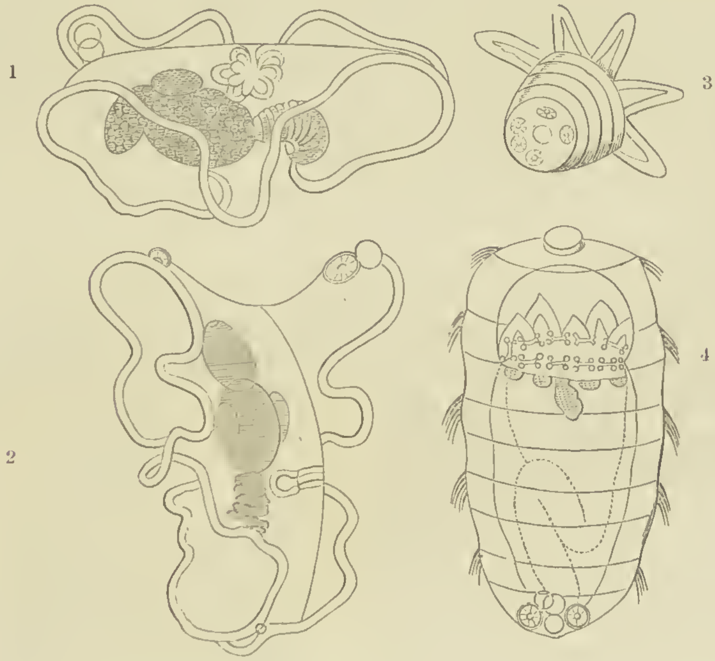
* Anat. der Röhren-Holothurie. Fol. 1816.

of the arterial system, in communication with which is the contractile vesicle (*f*); and this he looks upon as a reservoir for the nutritive fluid. From the circular vessel various arteries are given off: large branches pass into the tentacula around the mouth (*i*); so that these organs, besides being instruments of touch, from the extent of surface that they present and their great vascularity, are most probably important auxiliaries in respiration. Five other large arteries, derived from the same source (*k k*, *l*), pass backwards to supply the integuments of the body, and also to communicate by small cross branches with the little vesicular organs connected with the locomotive suckers, which, in the opinion of Delle Chiaje, are distended with the same blood as that which circulates through the rest of the body. The descending arteries, thus destined to supply the integument and distend the prehensile suckers, run in the centre of each of the five longitudinal fasciculi of the muscular tunic of the skin as far as the cloaca, and exhibit in their distribution a remarkable exception to the usual arrangement of the arterial system, which is generally found to divide and subdivide continually into smaller and still smaller canals: in the case before us there would seem to be no diminution in the size of the main trunks as they approach their termination; and the cross branches given off in their course, instead of ramifying, all end in the minute ambulacral vesicles, to the injection of which they would appear to be subservient.

Fig. 103.

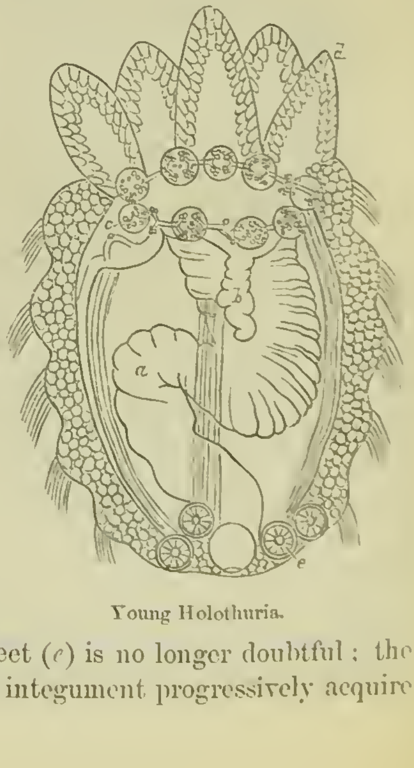


Embryology of *Holothuria.*

(539.) The generative system of the Holothuria is essentially similar to that found in the Asteridæ, consisting of long ovigerous cæca. The germs are secreted in slender ramified tubes (fig. 101, *h h*); these are collected into one great bundle, and open externally by a common canal in the neighbourhood of the mouth—not into the œsophagus, as Cuvier supposed, but upon the back of the animal. The generative cæca at certain times of the year become enormously distended, being at least thirty times as large as when not in a gravid state: if examined at this period, they are found to contain a whitish, yellowish, or reddish fluid, in which, in the female, the ova are suspended. In the male a precisely similar structure exists; but instead of ova, the cæca contain a fluid crowded with spermatozoa during the breeding season.

(540.) After their escape from the egg, the young Holothuriæ have been ascertained to undergo a kind of metamorphosis scarcely less wonderful than that observed in *Ophiura* and *Echinus*. In its first or *Pluteus* condition, the little embryo bears no resemblance whatever to the future animal, but swims vigorously about by the agency of broad membranous-looking expansions that surround the margins of its flattened body, wherein the stomach and other viscera are distinguishable (fig. 103, 1, 2). In its second stage of existence it has somewhat the appearance of a polype (fig. 103, 3); and this ultimately becomes converted into a larva-like being (fig. 103, 4), surrounded with several rows of vibratile cilia, by means of which its progression is accomplished. In the interior of this larva, a set of rudimentary oral tentacula, surrounded at their bases by a circle of calcareous spicula, is developed, an alimentary canal makes its appearance, and even the ampullæ Polianæ are distinctly recognizable, surrounding the position of the future mouth. In its fourth stage of advancement (fig. 104), the Holothurian structure is no longer doubtful, although the apparatus of vibratile cilia still exists upon the exterior of the body. The alimentary canal (*a*) may be seen to terminate in a cloacal chamber, the Polian vesicle (*b*) is largely increased in size, the calcareous circle (*c*) around the mouth is much strengthened, the tentacles (*d*) have assumed larger proportions, and even the appearance of the suctorial feet (*e*) is no longer doubtful; the longitudinal muscular fasciculi in the integument progressively acquire

Fig. 104.



Young Holothuria.

strength, and the little creature is transformed into the shape and attains the proportions of its parent.

(541.) The special instruments of touch, the only sense allotted to these animals, are the branched tentacula around the mouth, which seem by far the most irritable parts of the body. The nervous system is so obscurely developed, that even Delle Chiaje was unable to detect any traces of its existence; nevertheless there is little doubt of the presence of nervous threads in the muscular envelope of the animal, although, from the dense tissues wherein they are imbedded, it is next to impossible to display their course; most probably, as in the Echinus and Asterias, these communicate with a circular cord that embraces the œsophagus. No ganglia have as yet been discovered even in the *Holothuridæ*; and consequently, although the muscular actions of the body are no doubt associated by nervous filaments, the movements of these creatures appear rather to be due to the inherent irritability of the muscular tissues themselves, than to be under the guidance and control of the animal. In many species, the slightest mechanical irritation causes such powerful and uncontrollable contractions of the integument, that the thin membranes of the cloaca, unable to withstand the pressure, become lacerated, and large portions of the intestine and other viscera are forced from the anal aperture. So common, indeed, is the occurrence of this circumstance, that the older anatomists were induced to suppose that, by a natural instinct, the animals, when seized, vomited their own bowels. It is, in fact, extremely difficult to obtain perfect specimens of the Holothuridæ, from the constant occurrence of this accident: but, although annoying to the naturalist, such a phenomenon affords the physiologist an important lesson, teaching that here, as in the lower Zoophytes, the muscular system possesses an innate contractile power, which would seem only to be destroyed by incipient putrefaction; but so little is this contractility under command, that, once excited to an inordinate extent, it becomes totally unmanageable, even though its continuance inevitably causes the evisceration of the creature.

(542.) FISTULARIDÆ.—In order to complete our account of the organization of the Echinodermata, we have still to investigate the structure of the *Fistularidæ*—a group that, from the external appearance of the individuals composing it, and the total absence of the tubular feet met with in other families, has been improperly separated by some modern writers from the class under consideration. Nevertheless we shall find the position assigned to these animals by Cuvier to be in strict accordance with the character both of their outward form and internal structure; only, instead of placing them with the lowest of the Echinoderms, they would have been more properly situated at the head of the class, as most nearly approximating the Annelida in all the details of their economy. We have already given a description of the outward form of a Fistularia (§ 443), and seen the completely annulose condition of its body, although the radiating tentacula around the mouth are evidently analogous to those of the Holothuria, already described.

(543.) The *Sipunculus* inhabits shallow seas, concealing itself at the bottom in holes that it excavates in the sand. Having once located itself, it is seldom found to quit its concealment, but, retaining its hold upon the sides of the retreat which it inhabits, by dilating the posterior part of its body it occasionally protrudes its head from the orifice, either for the purpose of procuring food, or of respiring more freely the water of the ocean.

(544.) These animals are much sought after by fishermen, who employ them as baits for their hooks; and one species, *Sipunculus edulis*, is used in China as an article of food.

(545.) The body is covered externally with a delicate cuticle, easily separable by maceration or simple immersion in spirit; and when thus detached it forms so loose a covering, that Linnæus, deceived by the appearance of an animal thus preserved, applied to it the name of *Sipunculus saccatus*.

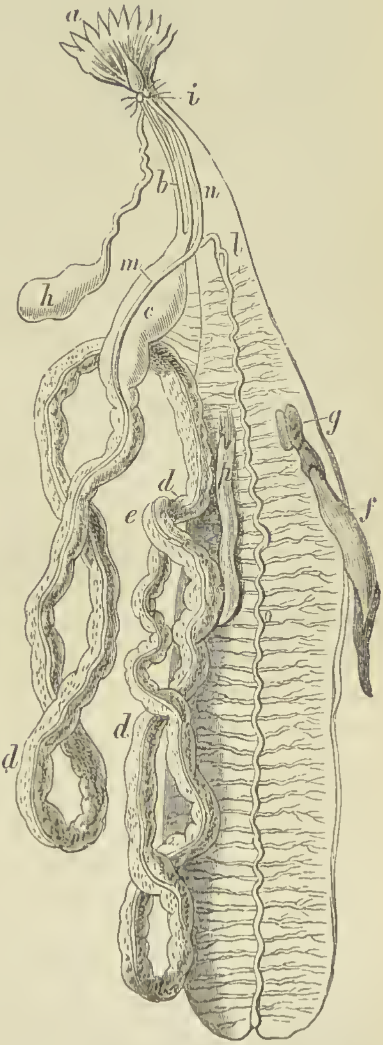
(546.) The muscular investment, placed beneath the skin, is composed of strong fasciculi arranged in three distinct layers. The external stratum is disposed in circular rings, beneath which spiral fibres may be observed crossing each other at various angles; and lastly, the inner coat is made up of about thirty powerful longitudinal bands, extending from one extremity of the body to the other. Such an arrangement is evidently sufficient for the general movements of progression; but in order to facilitate the retraction of the tentacular apparatus around the mouth, eight additional muscles surround the œsophagus: and by their action the whole of the oral apparatus is completely inverted and drawn inwards.

(547.) The tentacula around the oral orifice are the principal agents employed in seizing and swallowing food, an office to which they are peculiarly adapted by their great sensitiveness and power of contraction: but, as we have found to be generally the case among the Echinodermata, sand and fragments of shell form the great bulk of the contents of the intestine, so that it is by no means easy to state precisely the nature of the food upon which the Sipunculi are nourished.

(548.) The structure of the alimentary canal and of the nutrient apparatus conforms too accurately with what we have already seen in *Holothuria* to permit of a moment's hesitation concerning the relationship that exists between the apodous Echinodermata and the Holothuridæ. The œsophagus (fig. 105, *b*) is narrow, and soon dilates into a kind of stomachal receptacle (*c*): but, although the diameter of the intestinal tube is at this point perceptibly larger than in any other part of its course, there is no other peculiarity to distinguish it from the rest of the intestine. In the Annelida, the digestive apparatus is invariably straight, traversing the body from one extremity to the other.

—a circumstance that distinguishes them remarkably from the Echinoderms we are now considering; for in *Sipunculus* we find a digestive canal six or seven times the length of the animal, within which it is folded upon itself in various distinct convolutions. Leaving the stomach, if we may so call the dilatation above alluded to, it passes down (*d d d*) nearly to the tail, where it is reflected upon itself, and mounts up again as far as the point where it commenced; here it again turns back, and, once more reaching the bottom of the tegumentary sac, becomes a second time directed upwards, and re-ascends as far as the point *e*, where the anus is situated.

Fig. 105.



Anatomy of *Sipunculus*: *a*, oral tentacles; *b*, œsophagus; *c*, stomach; *d. d. d*, intestinal canal; *e*, position of anal orifice; *f*, *p*, ovaria; *g*, external orifice of ovary; *h*, ampulla Poliana; *i*, cerebral ganglia; *l*, heart; *m*, intestinal vein; *n*, branchial vessel; *o*, aortic trunk.

(549.) It is easy to account for this extreme length of the intestine when we consider the nature of the materials used as food, and the small proportion of nutriment contained among the sand and broken shells found in the digestive canal: but the remarkable position of the anal aperture is only explicable by a reference to the peculiar habits of the creature; for (living, as it does, in a narrow excavation bored in the sand, from which it seldom issues), had the excrements been discharged, as in *Holothuria*, through a terminal orifice, their constant accumulation at the bottom would soon expel the animal from its retreat; but, by the arrangement adopted, it is only necessary that the anterior part of the body should be protruded from its concealment, and the excrementitious matter may be cast out without inconvenience. The intestine is retained *in situ* and supported at all points by innumerable tendinous bands, that arise from the interior of the muscular walls of the body and form a kind of mesentery.

(550.) In *Sipunculus*, the character of the circulating system is in all essential points strictly analogous to that of the other Echinodermata; and moreover, from the superior concentration visible in every part, we have the multiplied organs of the other families exhibiting so much simplicity of arrangement, that whatever may have appeared obscure or complicated in our description of *Echinus* and *Holothuria* will receive elucidation from the diagrammatic form in which all the vessels connected with the circulation of the blood are represented in fig. 105. The intestinal vein (*m*) may be readily traced along the entire length of the alimentary canal: commencing near the anal extremity of the bowel, it follows all its convolutions, and receives from every part the minute vessels which ramify over the intestinal walls. These venous ramifications undoubtedly perform the office assigned to the lacteals of higher animals, and imbibe the nutritive particles furnished by digestion, which of course are conveyed into the great venous trunk (*m*). Arrived opposite to the termination of the œsophagus, the intestinal vein divides into two vessels: one performing the office of a branchial artery, by conveying a part of the blood to the respiratory organs in the neighbourhood of the mouth; the other, which we may call the aorta, distributing the remainder to all parts of the tegumentary system. The branchial vessel (*n*) runs from the bifurcation of the intestinal vein to the base of the oral tentacles, where it forms a vascular circle around the commencement of the œsophagus, analogous to that which we have seen in *Holothuria*; and in connexion with this circular vessel we find the "*ampulla Poliana*" (*h*), which Delle Chiaje conceives to be here, as in other cases, a receptacle for the circulating fluid. From the vascular circle around the mouth, vessels are given off to ramify minutely through the substance of the tentacula (*a*); so that these appendages may be considered as respiratory organs like those of *Holothuria*. The other vessels derived from the oral circle have not been traced; but we may conclude from analogy that arteries supplying the mouth and alimentary canal are furnished from this source.

(551.) The aorta (*o*) is the other large vessel derived from the intestinal vein, and is seen to pass in a flexuous course from its origin to the posterior extremity of the body, following the median line, and giving off transverse branches on both sides opposite to every ring of the muscular integument. At the commencement of the aorta is a dilated vesicle (*l*), which may be looked upon as a heart (*auricle*, Delle Chiaje). The vesicle alluded to is of a conical form, the apex of the cone being directed towards the tail of the animal; and, from the impossibility of making mercury pass from the aorta through this organ in the direction of the intestinal vein, it is probable that it contains an apparatus of valves so disposed as to prevent any retrograde motion of the blood. At the termination of the aorta there appears to be a second enlargement, to which the name of *ventricle* has been given, and which is perhaps also capable of contraction, so as to assist in the propulsion of the circulating fluid. The blood of these animals is of a purple colour in the veins, but red in the arterial vessels.

(552.) We have seen that the tentacula are, from their vascularity, well adapted to fulfil the office of a respiratory apparatus; but it may be presumed that they are not the only agents by which respiration is accomplished. Upon the outer surface of the body, in the neighbourhood of the anal opening, two apertures are visible, which lead into two long sacculi (*f*, *p*), the entrance being guarded by muscular fibres (*g*): their texture presents transverse and longitudinal striæ; and they contract spontaneously, even after the animal is dead; internally they are lined with a mucous membrane. The use of these organs is not precisely known; Cuvier regarded them as belonging to the generative system, while Delle Chiaje looks upon them as respiratory organs.

(553.) In this elevated form of the Echinodermata, so nearly allied to the Homogangliate type, we may naturally expect a more complete development of nervous ganglia than we have yet met with in the class; and accordingly we find, upon the anterior part of the œsophagus, two little nervous tubercles (*i*) from which nervous filaments issue to be distributed to different parts of the body; one of these, in particular, may be traced along the whole length of the intestine, from the mouth to the anus.

(554.) We are entirely ignorant concerning the mode of reproduction in these creatures. Nevertheless, at certain seasons of the year, on opening the visceral cavity it is found to be filled with a fluid of a reddish tint, in which thousands of minute white bodies resembling millet-seeds are seen to float: should these be ova, they are probably expelled through an orifice that exists in the vicinity of the tail.

CHAPTER IX.

HOMOGANGLIATA (Owen).

ARTICULATA (Cuv.). ANNULOSA (MacLeay).

(555.) THE next great division of the animal kingdom includes an immense number of living beings, adapted by their conformation to exist under a far greater variety of circumstances than any which we have hitherto had an opportunity of examining, all of which are obviously only adapted to an aquatic life, and accordingly are invariably found either to inhabit the waters around us, or to be immersed in the juices of living animals upon which they subsist. Even the Echinodermata are too imperfect in their construction to admit of their enjoying a terrestrial existence, inasmuch as, possessing no nervous centres adequate to give force and precision to their movements, they are incapable of possessing external limbs endowed with sufficient power and activity to be capable of progression upon land; neither are any of them furnished with organs of sense, that must be indispensable for the security of creatures exposed to those innumerable accidents to which the inhabitants of a rarer element are perpetually liable.

(556.) The type of structure met with in the HOMOGANGLIATA admits of far higher attributes and allows the enjoyment of a more extended sphere of existence: senses become developed proportionate to the increased perfection of the animal; limbs are provided endowed with strength and energy commensurate with the development of the nervous ganglia that direct and control their movements; and instincts are manifested in relation with the increased capabilities and more exalted powers of the various classes as they gradually rise above each other in the scale of animal development.

(557.) The most obvious though not the most constant character that distinguishes the creatures we are now about to describe is met with in their external conformation: they are all of them composed of a succession of rings formed by the skin, or outward integument, which from its hardness constitutes a kind of external skeleton, supporting the body, and giving insertion to the muscles provided for the movements of the animal. In the lowest forms of the ARTICULATA, the body is extremely elongated, and the rings proportionately numerous; the integument, moreover, is soft and yielding, and, as a necessary consequence, the limbs appended to the different segments are feeble and imperfect: such is the structure met with in the Worms, or ANNELIDANS, properly so called.

(558.) As we advance, we perceive the tegumentary rings to become less numerous, and the skin of a denser and firmer texture, adapted to sustain the action of stronger and more powerful muscles; the limbs likewise become more elaborately formed, their movements more free and energetic, and the instruments of sight and touch begin to assume considerable perfection of structure. This state of development we find in the MYRIAPODA, or *Centipedes*.

(559.) In the INSECTS, the concentration of the external skeleton is still more remarkable. The integument assumes a hardness and solidity proportioned to the vigorous movements of which the limbs are now capable; the rings or segments of the body, hitherto distinct, become more or less firmly soldered together in those parts where great strength and firmness are necessary, and scarcely any traces are left to indicate their existence as separate pieces; so that, instead of exhibiting that succession of similar segments seen in the Centipede, the body is apparently divided into three distinct portions: viz. the *head*, that contains the organs of the senses and the parts of the mouth; the *thorax*, sustaining the limbs, or instruments of progression; and the *abdomen*, enclosing the viscera subservient to nutrition and reproduction.

(560.) In a fourth division of articulated animals, namely the

Arachnidans, or *Spiders*, still further consolidation of the external skeleton is visible; for, in them, even the separation between the head and the thorax is obliterated, and it is in the abdomen only that the segments of the body are recognizable.

(561.) Lastly, among the Crustaceans we have various modifications of the outward skeleton, adapted to the habits of the different tribes. In the least perfect species, which are all aquatic, the segments of the skeleton are perfectly distinct and separate, resembling those of the Myriapoda; but in the stronger and more predacious tribes, the pieces of the head and thorax become solidly fixed together; and in those forms most adapted to a terrestrial life, namely the Crabs, almost all traces of distinction between the thoracic segments are lost in the construction of the calcareous shield that covers and protects their whole body.

(562.) We see, therefore, from the above rapid sketch of the different classes composing the articulated division of the animal kingdom, that, as their organization assumes greater perfection, the different segments of the external skeleton coalesce and become united together, so as to give greater strength to those parts more immediately connected with locomotion or the destruction of prey; let us next examine the nature of the nervous apparatus that characterizes the Homogangliata, and observe the relation which the outward form of the body bears to the arrangement of this primary system of the animal economy. In the humblest forms of the Annulosa, it would seem that every ring of the body contains a complete nervous apparatus, consisting of a pair of ganglia, and a set of nerves destined to supply the particular segment in which they are lodged. All these different brains, belonging to the individual segments, communicate with each other by nervous filaments, so that a continuous chain is formed, passing along the whole length of the body. With the exception of the anterior pair of ganglia, or those contained in the first ring, which we may call the *head*, the nervous centres are arranged along the ventral region of the body, that is, beneath the alimentary canal; but the anterior pair are invariably situated upon the dorsal aspect of the animal, and communicate with the rest by a nervous collar that embraces the commencement of the œsophagus. The nervous masses placed along the belly preside specially over the movements of the segments to which they belong, and have little to do with sensation, or the perception of external objects; whilst the anterior or cephalic pair, from the constancy of their communication with the organs of the senses, appear to be peculiarly in relation with the perceptive faculties of the creature.

(563.) It may be taken as a general law, that the perfection of the nervous system of any animal may be estimated by the proportionate size of the central ganglia, upon the development of which both the energy of the actions of the body and the completeness of perception depend; and by following out this great principle, we shall be easily able to account for the progressive steps whereby the Articulata become more and more perfectly organized, as we trace them in the series above indicated. In proportion as we have found the segments of the body to become less numerous, the appended limbs stronger, the outward skeleton more dense, and the muscular powers more energetic, we shall find the abdominal ganglia to diminish in number by becoming consolidated into larger masses, increasing in size and energy in accordance with the development of the limbs over which they preside; and, in the same manner, we shall observe the senses assume greater perfection of structure, and the instincts become more developed, as we find the cephalic or anterior pair of brains increasing in proportionate bulk.

(564.) Among the Homogangliata are likewise to be detected the first traces of the *sympathetic* or *splanchnic* nervous system. This consists of delicate filaments which are distributed upon the alimentary canal, presenting, in their course, ganglionic enlargements, and anastomosing, some with the œsophageal ring, and others with the cerebral or encephalic ganglia*.

(565.) These observations will suffice to introduce the student to the Homogangliate division of the animal world, and to direct his attention to those physiological points connected with the nature of their nervous system which will be more fully laid before him in the following pages.

CHAPTER X.

ANNELIDA.

(566.) The lowest class of articulated animals comprehends an extensive series of creatures generally grouped together under the common name of *Worms*. In the outward form of their bodies many of them resemble some of the more perfect Entozoa, and we need not therefore be surprised that, in ordinary language, they are frequently confounded together. But whatever may be the similarity in outward appearance between the more perfect intestinal worms and the animals belonging to the class upon the consideration of which we are now entering, the examination of their anatomical structure will at once show that they differ widely from each other, and have thus been properly separated by a considerable interval in all the more modern systems of zoological arrangement.

(567.) The principal characters which serve to distinguish the Annelida from other forms of the animal world are readily appreciated.

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* *Vide* Brandt, Bemerkungen über die Mundmagen- oder Eingeweidenerven der Evertebraten. Leipzig, 1835.

and, when once pointed out, will be found sufficient for the guidance of the most superficial observer. The body is always considerably elongated, and composed of a succession of rings or segments that, with the exception of the first and last, scarcely differ from each other except in size. Each ring is generally found to be furnished with a set of short spines or setæ, calculated to assist in locomotion; but in no instance are these animals provided with articulated legs. The first segment of the body, which may be called the head, contains the mouth, sometimes provided with a formidable apparatus of jaws; it is also generally furnished with eyes, and variously-shaped tentacula, apparently instruments of touch. Tho last segment also not unfrequently presents setiform appendages, and occasionally a prehensile sucker, used as an organ of progression.

(568.) Their blood is sometimes remarkable for its red colour, and circulates in a double system of arteries and veins; respiration is effected either in the general cavity of the body, or by means of arborescent tufts appended to various parts of their external surface; moreover they are almost all hermaphrodite, and generally require the congress of two individuals for mutual impregnation.

(569.) Abranchiata.—This order comprises two distinct tribes, that differ widely in their habits and external appearance: the first comprehends the Leeches (*Annelida suctoria*), distinguished by the existence of a prehensile sucker situated at each extremity; while in the second, instruments of attachment are totally wanting, the only external appendages to the body being a number of minute and almost imperceptible bristles, which project from the different segments and assist in progression: such are the Earthworms, &c. (*Annelida terricola*).

(570.) The common Leech (*Hirudo medicinalis*) affords the most interesting example of a suctorial Annelid. The outward form of one of these animals is familiar to every one, and their general habits too well known to require more than a brief notice. The body is very extensible, and divided by a great number of transverse lines into numerous rings, apparent in the contracted state of the animal, but nearly imperceptible when the body is elongated. The skin is soft, being merely a thin cuticular pellicle separable by maceration; and the surface is lubricated by a copious secretion of mucus. Beneath the cuticle is a layer of coloured pigment, upon which the colours of the animal depend; but the cutis, or true skin, is so intimately connected with the muscular integument of the body, that its existence as a distinct tunic is scarcely demonstrable. The muscular coverings or walls of the body, which form a kind of contractile bag enclosing the viscera, are found, upon accurate dissection, to consist of three distinct strata of fibres running in different directions. The outer layer is composed of circular bands, passing transversely; in the second the fibres assume a spiral arrangement, decussating each other; while the internal layer is made up of longitudinal muscles, extending from one end of the creature towards the opposite. Such an arrangement is evidently adequate to the production of all needful movements, and capable of giving rise to all the motions connected with the elongation, contraction, or lateral inflexions of the body used in progression.

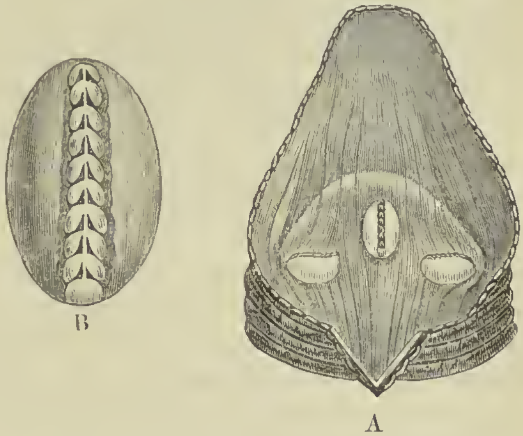
(571.) At each extremity of the animal, the muscular coat expands into a flattened fleshy disk, composed of circular and radiating fasciculi, which, when applied to a smooth surface, perform the office of suckers, and thus become important instruments of prehension. There are no vestiges of external limbs; nevertheless, with the simple mechanism above described, the Leech is able to crawl with considerable rapidity along the surface of subaquatic plants, or even to swim with much facility through the water. The first method of locomotion is accomplished by means of the terminal suckers. Supposing the posterior disk to be attached, the animal elongates its body to the utmost, and then fixes the sucker placed at the opposite extremity; this done, the hinder parts are drawn forward and again fixed, preparatory to a repetition of the process. In swimming, the whole body is elongated, and by some partial contractions of the muscular integument, not precisely understood, assumes the appearance of a flattened band; in this condition the Leech makes its way through the element it inhabits by successive undulatory movements of the body, performed with much grace and elegance.

(572.) The mouth of the Leech is an exceedingly complete apparatus, adapted not only to the destruction of minute aquatic animals that constitute its usual food, but, as is universally known, admirably fitted to extract blood from the higher animals; combining, in its operation, the offices both of the cupping-glass and the scarificator.

(573.) The mouth is situated near the centre of the anterior sucker, so that the oral aperture is firmly applied to any surface upon which this part of the animal is fixed. Around the entrance of the œsophagus are disposed three minute cartilaginous teeth, imbedded in a strong circle of muscular fibres (fig. 106, A). Each tooth has somewhat of a semicircular form, and, when accurately examined with a microscope, is found to have its free margin surmounted with minute denticulations (fig. 106, B), so as to resemble a small semicircular saw. On watching a leech attentively during the process of biting, the action of these teeth is at once evident; for, as the skin to which the sucker is adherent is rendered quite tense, the sharp serrated edges of the teeth are pressed firmly against it, and, a sawing movement being given to each cartilaginous piece by the strong contractions of the muscular fibres around the neck, these instruments soon pierce the cutis to a considerable depth and lay open the cutaneous vessels, whence the creature sucks the fluid which its instinct prompts it to seek after with so much voracity. The position of the teeth around the opening of the mouth, as represented in the subjoined figure (fig. 106, A), will at once explain the cause of the triradiate form of the incision that a leech-bite invariably exhibits.

(574.) On contemplating this singular dental apparatus found in the medicinal Leech, and considering the nature of the food upon which it usually lives, it is difficult to avoid arriving at the conclusion that such a structure is rather a provision intended to render these creatures subservient to the alleviation of human suffering than necessary to supply the wants of the animals themselves. In the streams and ponds where they usually inhabit, any opportunity of meeting with a supply of the blood of warm-blooded vertebrata must be of rare occurrence; so that comparatively few are ever enabled to indulge the instinct that prompts them to gorge themselves so voraciously when allowed to obtain it: neither does it appear that the blood which they swallow with so much avidity is a material properly suited to afford them nourishment; for although it is certainly true that it will remain for a considerable time in its stomach without becoming putrid, yet it is well known that most frequently the death of the Leech is caused by such inordinate repletion, provided the greater portion of what is taken into the body is not speedily regurgitated through the mouth.

Fig. 106.

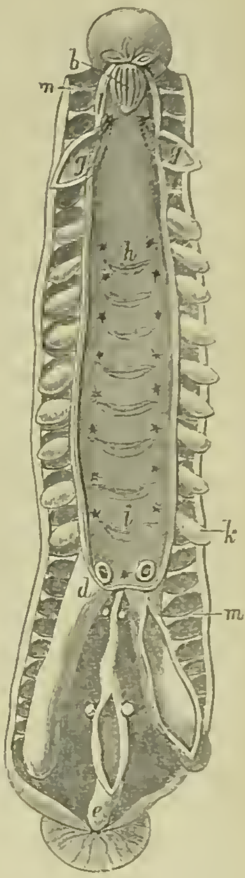


Dental apparatus of the Leech. A, triradiate arrangement of the teeth or saws; B, a tooth magnified.

(575.) The internal digestive apparatus is evidently adapted, from the construction of all its parts, to form a capacious reservoir for the reception of fluids taken in by suction: the stomach, indeed, with the numerous lateral appendages opening from it on each side, would seem to fill the whole body; and, being extremely dilatable, allows the animal to distend itself to a wonderful extent, so that it is not unusual to see a leech, when filled with blood, expanded to five or six times the dimensions natural to it in an empty state.

(576.) The stomach itself (fig. 107, *h*, *i*) occupies about two-thirds of the visceral cavity; on opening it, as represented in the figure, it is seen to be divided by delicate septa into nine or ten compartments that communicate freely with each other. In each compartment we observe two lateral orifices leading into as many wide membranous pouches (*k*), which, although shrunk and flaccid when in an undistended condition, as they are seen in the figure, are easily filled with fluid introduced into the stomach, and are then swelled out into very capacious bags. Perhaps the simplest way of obtaining a correct idea of the relative sizes and general arrangement of these organs is to make a cast of their internal cavities when in a state of distention ; this is readily effected by placing a dead leech in warm water until it is slightly heated : in this state, the pipe of a small injecting syringe can be introduced into the œsophagus, so as to fill the stomach and cæca with common wax injection ; and if the body be immediately removed into a vessel of diluted muriatic acid, the soft parts will be speedily destroyed, leaving an exact model of the interior. It will then be seen that the lateral cæca increase gradually in size as they approximate the posterior extremity of the body, until the last pair (*d*) become so large as nearly to fill up the space intervening between the end of the stomach and the anal boundary of the visceral cavity.

Fig. 107.



Digestive organs of the Leech (*Hirudo medicinalis*) : *b*, mouth : *h, i*, interior of the stomachal cavity, exhibiting the openings of the lateral cæca (*k*) : *g*. first pair of stomachal cæca : *d*. last pair, extending backwards on each side of the intestine *e*.

(577.) The small size of the intestine (*e*) when compared with the capacious stomach described above is remarkable : it commences by a minute orifice at the termination of the digestive cavity, and becoming slightly enlarged, passes in a straight line, lodged between the two posterior cæca, to the anus, which is an almost imperceptible aperture placed at the root of the posterior sucker : four small and apparently glandular masses are appended to this short canal ; but their nature is unknown. The entire alimentary apparatus is retained *in situ* by numerous membranous septa (*m m*), passing between its outer walls and the muscular parietes of the body.

(578.) In the Leech, the circulating system is more highly developed than in any other Annelid*. The presence or absence of a heart-like centre to this system in this class of animals is by no means the true criterion of the degree of its evolution. The amount of blood relatively to the size of the body, the degree of capillary subdivision which occurs on the periphery of the blood-system, and the proportion of the latter to the peritoneal fluid, form far more correct indications. In the Leech there exists no free space between the intestine and the integument : to this anatomical fact the highest interest will be shown to belong when explaining the mechanism of respiration in this Annelid. Here the chylous fluid, which in nearly all other Annelids occupies the general cavity of the body, like a cylindrical fluid stratum, separating the intestine from the integument, is transferred into the *interior* of the lateral diverticula of the stomach. The peritoneal chamber, being no longer required, is obliterated by the adhesion of the intestine to the integument: the union of these parts is effected through the medium of a dense spongy layer of capillary blood-vessels, the contents of which are exposed internally to the influence of the fluid contained in the digestive cæca, and externally to that of the surrounding element: hence the mechanism of the respiratory process, and the power enjoyed by this and other abranchiate Annelids of disponsing with all external breathing appendages.

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* *Vide* Dr. Williams's Report on the British Annelida, in the Reports of the British Association for the Advancement of Science for 1851.

(579.) Whilo, however, the peripheral segment of the vascular system in the Leech exhibits proofs of great complexity, the main currents of the blood obey two leading directions. If the body of the worm be longitudinally bisected by an imaginary horizontal plane into a dorsal and ventral semicylinder, then the blood in the primary trunks of the dorsal half will move from the tail towards the head, and in the ventral half from the head towards the tail: this movement prevails equally in the great longitudinal trunks of the integuments and alimentary canal. The transverse or circular movement of the blood is performed by means of branches which run between the main longitudinal vessels: this latter system is divisible into as many portions as there are rings in the body of the worm: each segment of the body under this arrangement has its own independent circulation, transverse and longitudinal. Thus the currents describe two excentric ellipses, cutting each other at right angles. Of course, the segmental divisions of the general system communicate with each other at every part, while the longitudinal trunks are common to all the segments. From this description it is manifestly impossible that a distinction of venous and arterial blood can exist in the circulating fluid of this Annelid; in every part of the circumference of each ring the blood is being arterialized as it is being rendered venous; the two opposite processes proceed simultaneously in the same capillary system. The blood must be, therefore, as arterial and as venous at one and the same time in the dorsal as in the ventral trunks; notwithstanding, the dorsal main is recipient, the ventral distributive of the blood: all the secondary currents converge upon the former, and emanate from the latter; the blood in both is nevertheless identical in physiological properties.

(580.) In addition to the main dorsal and ventral trunks, there exist in the Leech two strong and obvious lateral trunks, one on each side (fig. 108, *e e*). The *branches* exhibit in their walls a structure precisely the same as that which distinguishes the vascular system in every other part of the body, while the *primary lateral trunks* are provided with remarkable muscular parietes, their fibres being of the striped kind. The fascicle of the muscle composing the walls is arranged in a manner which is quite distinctive of, and peculiar to, this vessel; it is coiled with so much regularity as to enclose a perfect cylinder, in which the blood flows: the longitudinal fibres are all suppressed, and therefore the circular fascicles, lined within by a hyaline membrane, constitute exclusively the coat of the vessel. Such a vessel is almost unique in structure in the animal series; but none other would perform so admirably the peculiar duties for which it is introduced into this part, obviously as a special provision. Its business is to transmit with augmented force a current of blood in a transverse direction from the side to the ovario-uterine organs (fig. 108, *f f*), which form a double longitudinal series, one on either side of the ventral mesial line in each annular segment of the body. An express branch from the latero-abdominal trunk on either side is furnished to these reproductive organs (fig. 108, *h h*); so that the amount of blood propelled by this vessel, measured in its totality, must be very considerable, and the quantity during the generative season must undergo great increase in consequence of the augmentation of size which at that period these organs experience. The lateral longitudinal vessel is strikingly adapted to meet such alternation of extremes: constructed of muscle, it readily yields, under the *flow* of the blood-tide to the organs to whose wants it ministers, and its parietes augment by accelerated nutrition during the periods of increased local determination of blood: formed of any other structure than muscle, such admirable adaptive alternations could not happen.

Fig. 108.

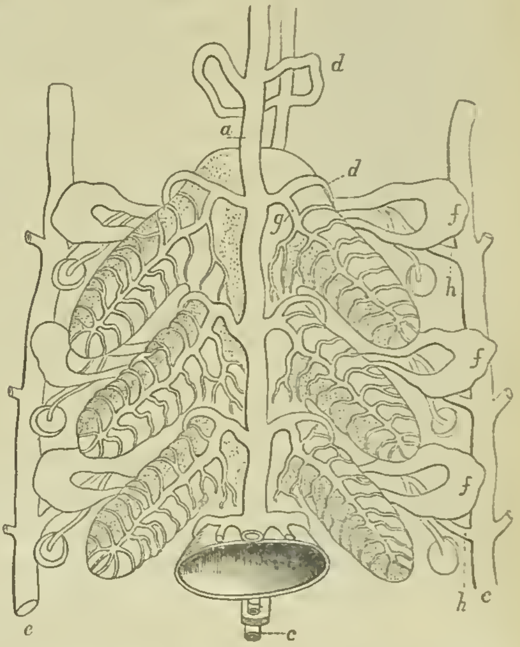

Diagram illustrative of the circulatory apparatus in the Leech (*Hirudo medicinalis*). (After Dr. Williams.) *a*, great dorsal vessel; *c*, ventral vessel; *d d*, intercommunicating vessels between dorsal and ventral trunks: *e c*, lateral abdominal trunks; *f f f*, ovario-uterine organs; *g*, vessels distributed over the cæcal appendages to the stomach; *h h*, branches from the lateral abdominal trunks supplying the ovario-uterine apparatus.

(581.) It has been generally considered that, in the abranchiate Annelidans, the organs provided for respiration are a series of membranous pouches, communicating externally by narrow ducts, or spiracles, as they have been termed, into which aërated water is freely admitted. These sacculi, in the Leech, are about thirty-four in number, seventeen being visible on each side of the body; they are extremely vascular; and in connexion with every one of them there is a long glandular-looking appendage, represented in fig. 110, *m*.

(582.) According to the views of M. Dugès, which, previous to the appearance of Dr. Williams's interesting memoir, were received with general assent, the two lateral vessels in the Leech are appropriated to the supply of this respiratory system, and in them the blood moves in a circle quite independent of that formed by the dorsal artery and ventral vein, although they all communicate freely by means of cross branches, those passing from the lateral vessels to the dorsal being called by M. Dugès* *dorso-lateral*, while those which join the lateral trunks to the ventral canal are the *latero-abdominal* branches of that observer. The movement of the blood in the lateral or respiratory system of vessels is quite distinct from that which is accomplished in the dorso-ventral or systemic trunks: sometimes it passes down one of these vessels from the head towards the tail, and in an opposite direction on the other side of the body; but in a short time the movement of the currents will be seen to become completely reversed, so that an undulatory motion, rather than a complete circulation, is kept up. By this action of the lateral canals the blood is made perpetually to pass and repass the respiratory sacculi; and, opposite to each of these, branches are given off which form so many independent vascular circles, representing very closely the minor or pulmonary circulation of higher animals.

(583.) On examining attentively one of the "respiratory pouches," according to the same authority, its membranous walls are seen to be covered with very fine vascular ramifications (fig. 109, *f*), derived from two sources: the latero-abdominal vessel (*d*) gives off a branch (*e*), which is distributed upon the respiratory sacculus; and there is another very flexuous vascular loop (*b*), derived from the lateral vessel itself (*a*), which terminates by ramifying upon the vesicle (*f*) in a similar manner. The walls of tho loop (*b*) are extremely thick and highly irritable; but on tearing it across, the internal cavity or canal by which it is perforated is seen to be of comparatively small diameter; so that we are not surprised that, although such appendages to the respiratory sacs were detected and well delineated by former anatomists†, their nature was unknown, and they were supposed to be glandular bodies appropriated to some undiscovered use. From the arrangement above described, M. Dugès was led to believe that small circular currents of blood exist, which are independent, to a certain extent, of the general circulation, and that opposite to each membranous bag a portion of the fluid contained in the lateral vessel (*a*) is given off through the muscular tube (*b*) (which thus resembles a pulmonary heart), and, after being distributed over the walls of the supposed respiratory vesicle, and in this manner exposed to the influence of oxygen, the blood returns into the general circulation*.

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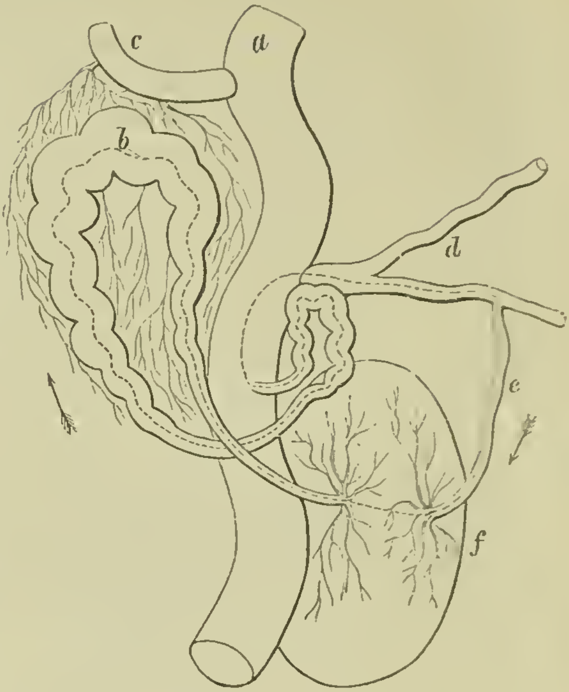
* Ann. des Sci. Nat. vol. xv.

† Delle Chiaje, *op. cit.* Moquin-Tandon, Monographie sur la famille des Hirudinées. 4to, Montpellier, 1827.

Fig. 109.



Respiratory organs of the Leech, according to M. Dugès: *a*, lateral vessel; *b*, pulmonary heart; *c*, dorso-lateral branch; *d*, latero-abdominal vessel; *e*, afferent pulmonary branch; *f*, respiratory sacculus.

(584.) The nervous system of the Leech (fig. 110, *k*) consists of a long series of minute ganglia joined by connecting filaments: of these, about twenty-four are situated along the ventral surface of the body. The anterior pair, or that immediately beneath the œsophagus, is larger than the rest, forming a minute heart-shaped mass, which is united, by a delicate nervous collar embracing the gullet, with two small nodules of neurine situated upon the dorsal aspect of the mouth. The two minute ganglia last mentioned form that portion of the nervous system most intimately connected with sensation; for, while the nervous filaments given off from the abdominal ganglia are distributed to the muscular integuments of the body, the nerves which issue from the supra-œsophageal pair supply the oral sucker, where the organs of the senses are situated. In all the Homogangliata, indeed, it is exclusively from this cephalic pair of ganglia that the nerves appropriated to the instruments of the senses are derived; and we shall therefore not hesitate in the following pages to apply to this part of the nervous system of the Articulata the name of *brain*; considering it to be strictly analogous, in function at least, with the cerebral masses of more highly organized beings.

* As will be seen further on, the so-called "*pulmonary hearts*" of M. Dugès are regarded by Dr. Williams as *ovario-uterine organs.*

(585.) The splanchnic system in the Leech consists of three small ganglia, situated in front of the brain, with which they are connected by delicate nervous filaments. All three send branches to the parts around the mouth and to the inferior surface of the alimentary apparatus*.

(586.) When, however, we regard the minute size of these as yet rudimentary nervous centres, we cannot expect to find them associated with any very perfect apparatus of sensation. The oral sucker, indeed, seems to possess a more delicate sense of touch than the rest of the body, adapting it to examine the surface to which it is about to be fixed; and probably the Leech may enjoy, in some measure, perceptions corresponding with those of taste and smell. These senses have been found to exist in many of the animals we have already described; but in the *Hirudinidæ* we have, in addition, distinctly-formed organs of vision, exhibiting, it is true, the utmost simplicity of structure, but nevertheless corresponding, in the perfection of their development, with the condition of the cerebral masses in relation with them.

(587.) The eyes of the Leech are eight or ten in number, and are easily detected, by the assistance of a lens, under the form of a semicircular row of black points, situated above the mouth, upon the sucking surface of the oral disk,—a position evidently calculated to render them efficient agents in detecting the presence of food. The structure of these simple eyes, according to Professor Müller†, does not as yet present any apparatus of transparent lenses adapted to collect or concentrate the rays of light; but each ocellus, or visual speck, would seem to be merely an expansion of the terminal extremity of a nerve derived immediately from the brain, spread out beneath a kind of cornea formed by the delicate and transparent cuticle: behind this is a layer of black pigment, to which the dark colour of each ocular point is due.

(588.) Leeches, like the generality of the Annelida, are hermaphrodite, every one possessing two complete systems of generative organs, one subservient to impregnation, the other to the production of the ova; nevertheless these animals are not self-impregnating, but the congress of two individuals is essential to fecundity.

(589.) Commencing with the male organs, we are not surprised to find the testes divided into numerous distinct masses, or, rather, repeated again and again, in conformity with a law to which we have already alluded. The glands that apparently secrete the seminal fluid are about eighteen in number (fig. 110, *e*, *f*), arranged in pairs upon the floor of the visceral cavity. Along the external edge of each series there runs a common canal, or *vas deferens*, which receives the secretion furnished by all the testicular masses placed upon the same side of the mesial line, and conveys it to a receptacle (*d*), where it accumulates. The two reservoirs, or *vesiculæ seminales* (*d d*), if we may so call them, communicate with a muscular bulb (*c*) situated at the root of the penis.

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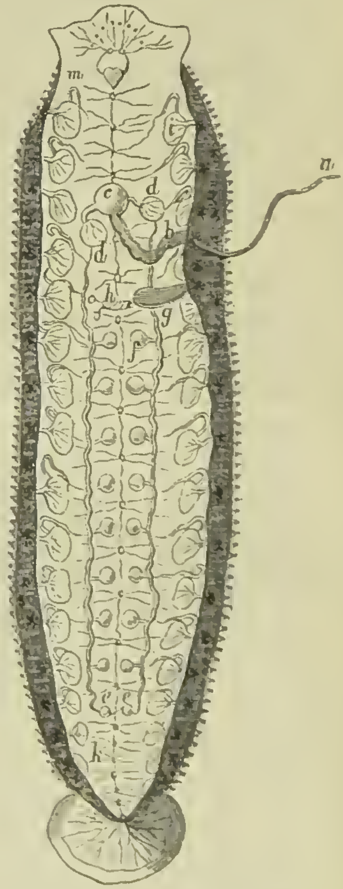
* See Brandt und Ratzeburg, Med. Zool. tab. 29.

† Ann. d. Sci. Nat. vol. xxii.

The penis itself (*a*) is frequently found protruded from the body after death; it is a slender tubular filament, which communicates by its origin with the contractile bulb (*c*), and, when retracted, is lodged in a muscular sheath (*b*). The male apparatus is thus complete in all its parts: the fecundating secretion derived from the double row of testes is collected by the two *vasa deferentia* and lodged in the receptacles (*d d*); it is thence conveyed into the muscular cavity (*c*) situated at the root of the male organ of excitement, through which it is ultimately ejected.

(590.) The ovigerous or female sexual organs of the Leech are more simple in their structure than those that constitute the male system. They open externally by a small orifice situated immediately behind the aperture from which the penis is protruded, the two openings being separated by the intervention of about five of the ventral rings of the body. The vulva, or external canal, leads into a pear-shaped membranous bag (fig. 110, *g*), which is usually, but improperly, named the uterus. Appended to the bottom of this organ is a convoluted canal (*h*), that communicates with two round whitish bodies; these are the ovaria. The germs which are formed in the ovarian corpuscles, therefore, escape through the tortuous duct (*h*) into the uterus (*g*), where they are detained for some time, prior to their ultimate expulsion from the body. The exact nature of the uterine sacculus, as it is called, is imperfectly understood: some regard it as a mere receptacle wherein the seminal fluid of the male is received and retained until the ova come in contact with it as they pass out of the body, and thus are subjected to its vivifying influence; other physiologists believe that the germs escape from the ovaria in a very immature condition, and suppose that during their sojourn in this cavity they attain to more complete development before they are ripe for exclusion; while some writers go so far as to assert that leeches are strictly viviparous, inasmuch as living young have been detected in the interior of this viscus; but all these suppositions are easily reconcilable

Fig. 110.



Generative apparatus of the Leech.

with each other. There is no doubt that the seminal liquor is deposited in this reservoir during the copulation of two individuals; neither would any one dispute that the ova are collected in the same cavity before they are expelled from the body. As to the discussion whether the young are born alive or not, or, as it is generally expressed, whether leeches are oviparous or viviparous, it is in this case merely a question of words; for, in a physiological point of view, it cannot make the slightest difference whether the ova are expelled as such, or whether, owing to their being retained by accidental circumstances until they are hatched internally, the young leeches make their appearance in a living state.

(591.) Leeches are oviparous. The ova remain in the uterus for some time, where they become invested, first with a serous membrane, and then with a glutinous fluid which remains attached to them after their expulsion, and serves as a protecting covering after they are deposited in the clay and holes of the sides of ponds. They generally deposit these cocoons from May to the end of September.

Such was the generally received view of the arrangement of the generative organs of these Annelidans, as given in the first edition of this work. We will now proceed to describe the reproductive system of the Leech, as deciphered by Dr. Williams in his most recently published version*:—

(592.) The segmental organs of the Leech tribe exist under very readily demonstrated conditions. After pinning the common leech down carefully to the trough, and opening the body by a longitudinal incision along the dorsal aspect, the whole stomach and its diverticula must be minutely picked away. The dissection should then be washed with very gentle streams of fresh cold water, in order to remove the blood, which obscures everything. The object being thus carefully cleansed, and then floated in water, a full view of the segmental ovarian and the median testicular systems will present itself.

(593.) The one consists of a bilateral series of extremely delicate, floating, pearly-looking membranous organs, equalling in the number of their pairs that of the annuli marked upon the integument. The other, more medianly situated and bilateral, also consists of two series (one on either side) of little spherical white bodies, tied together by an intermediate thread, which unite at a common point anteriorly. A third element should be noticed, namely the small *sacculus*, which, immediately behind the anterior mass of the united testes, lies also on the median line.

(594.) According to Dr. Williams, every segmentary organ in the body of the Leech is not only an excretionary instrument for the discharge of the cavitary fluid, but is also an ovary. The tube which proceeds from one limb of the organ and terminates in a spherical membranous vesicle is the counterpart of the ciliated extremity of the segmental organs of *Nais* and *Lumbricus*. Both open into the cavity of the body. In the

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* Phil. Trans. 1858.

Leech, however, neither the vesicle, nor the tube into which it is prolonged, is ciliated, but, in lieu, they are highly contractile. The vesicle is the respiratory *sacculus* of Dugès (§ 581). It does not, as Dugès contends, communicate externally by an orifice in the integument, but internally. The tube which supports this vesicle arises from that limb of the segmental organ which contains the ova in their least-developed condition. It is probable therefore that the chylaqueous fluid which this tube is designed to discharge flows throughout the entire extent of the organ, from the point of entrance to that of exit, before it escapes externally. In this course the fluid may afford the materials of nourishment to the ova as they travel from one limb to another of the looped organ.

(595.) The organ itself may be described as a looped tube, the limbs of which, returning upon themselves, and one invaginating the other, open externally at the same point. In order to examine further these delicate organs, they must be cut out, as closely to the abdominal surface as possible, by means of a curved pair of scissors. They should then be floated in water on a glass slide, covered by a thin slip, and placed under the microscope. If they have been successfully dissected out, it will be seen that one limb is broader and more transparent than the other: in the former limb the ova are merely pellucid cells, consisting exclusively of the germinal vesicle and germinal spot; in the latter limb the ova have acquired their full complement of vitellus. At this stage they exhibit a flattened ovoid form. This fact affords a demonstration as to the course taken by the ova in their passage from the ovary, properly so called, towards the exterior. The seat of the true ovary, or that part which is endowed with the special power of ovogenesis, is marked by the plexus of vessels. In relation to this special centre, all the rest of the organ may be characterized as the oviduct; but it is also a *vitellarium*. It follows therefore that, in the Leech tribe, the ova at no time reach the cavity of the body: this may be one reason why, in this family, the perigastric cavity is so contracted, and the contained fluid so reduced in volume.

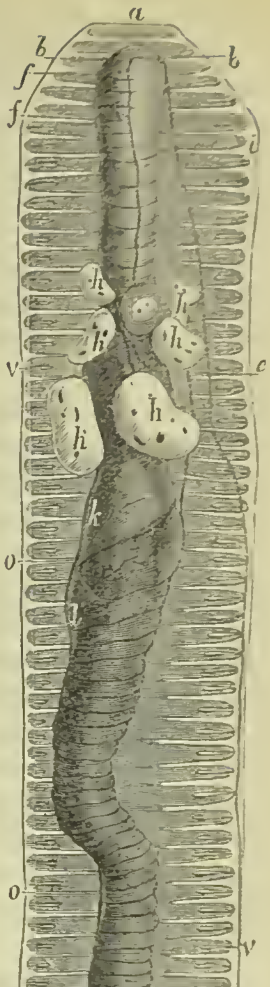
(596.) Abranchia terricola.—The species belonging to the second division of those Annelidans which possess no external organs of respiration are easily distinguishable from the suctorial worms by the different construction of their instruments of locomotion. They live in general beneath the surface of the ground, either perforating the soil in all directions, as the Earthworms (*Lumbrici*), or burying themselves in the mud upon the sea-shore or of freshwater streams, where many of them, called *Naides* (*Nais*, Linn.), live a semi-aquatic life. In conformity with such habits, their entire structure is adapted to a subterranean existence, and their bodies are so organized as to enable them to burrow with facility through the dense and unyielding materials wherein they are usually found. Whoever has attentively watched the operations of an Earthworm when busied in burying itself in the earth, must have been struck with the seeming disproportion between the laborious employment in which it is perpetually engaged, and the means provided for enabling it to overcome difficulties apparently insurmountable by any animal unless provided with limbs of extraordinary construction and possessed of enormous muscular power. In the Mole and the burrowing Cricket we at once recognize, in the immense development of the anterior legs, a provision for digging, admirably adapted to their subterranean habits, and calculated to throw aside with facility the earth through which they work their way; but in the worms before us, deprived as they appear to be of all external members—feeble and sluggish even to a proverb,—where are we to look for that mechanism whereby they are enabled to perforate the surface of the ground, and to make for themselves, in the hard and trodden mould, the pathways that they traverse with such astonishing facility and quickness?

(597.) The structure of the outer fleshy integument of the Earthworm resembles in every respect that of the Leech, already described, both in the annular arrangement apparent externally, and the disposition of the muscular strata. The suctorial disks, however, that in the Leech formed such important instruments of progression, are here totally wanting; and the annular segments of the body, as they approach the anterior extremity, become gradually diminished in size, so as to terminate, when the worm is fully stretched out, in a fine point, near the apex of which is the opening of the mouth. But there is another circumstance wherein the external anatomy of the terricolous Annelidans differs materially from what we have seen in the suctorial Abranchia: in the latter, the tegumentary segments were quite naked upon their outer surface; but in the *Lumbrici*, of which we are now speaking, every ring, when examined attentively, is found to support a series of sharp retractile spines or prickles; these, indeed, are so minute in the Earthworm, that, on passing the hand along the body from the head backwards, their presence is scarcely to be detected by the touch, but they are easily felt by rubbing the animal in the opposite direction,—a circumstance arising from their hooked form, and from their points being all turned towards the tail. These differences between the external structure of the suctorial and setigerous Abranchia, minute and trivial as they might seem to a superficial observer, are, however, all that are required to convert an aquatic animal into one adapted to a subterranean residence, as will be evident to any one who observes carefully the manner in which the Earthworm bores its way through the soil. The attenuated rings in the neighbourhood of the mouth are first insinuated between the particles of the earth, which, from their conical shape, they penetrate like a sharp wedge; in this position they are firmly retained by the numerous recurved spines appended to the different segments: the hinder parts of the body are then drawn forwards by a longitudinal contraction of the whole animal—a movement that not only prepares the creature for advancing further into the soil, but, by swelling out the anterior segments, forcibly dilates the passage into which the head had been already thrust; the spines upon the hinder rings then take a firm hold upon the sides of the hole thus formed, and, preventing any retrograde movement, the head is again forced forward through the yielding mould, so that, by a repetition of the process, the animal is able to advance with the greatest apparent ease through substances which it would at first seem utterly impossible for so helpless a being to penetrate.

(598.) The alimentary canal of the Earthworm is straight and very capacious. Its great size, indeed, is in accordance with the nature of the materials employed as food; for it is generally found distended with earth; and by the older physiologists these creatures were regarded as affording proof that the nourishment of animals was not exclusively derived from animal and vegetable substances, since in this case they supposed nutriment to be obtained from matter belonging to the mineral kingdom. This supposition, however, has been long since exploded; for it is not from the earth that nourishment is afforded, but from the decaying animal and vegetable particles mixed up with the soil taken into the stomach; so that the exception to the general law of nature supposed to exist in the Earthworm has no foundation in truth. The whole intestinal tract of one of these animals is represented in fig. 111: it consists of a wide œsophagus which terminates in a crop-like dilatation; to this succeeds a muscular gizzard (*k*), and a long sacculated intestine (*l l*) that passes in a direct line to the anus.

(599.) In the Earthworm, says Dr. Williams, the chylaqueous fluid is almost entirely suppressed, and the visceral cavity obliterated. This vulgar worm, however, does not breathe on the atmospheric, but on the aquatic principle. It dies rapidly in perfectly dry places. Its cu-

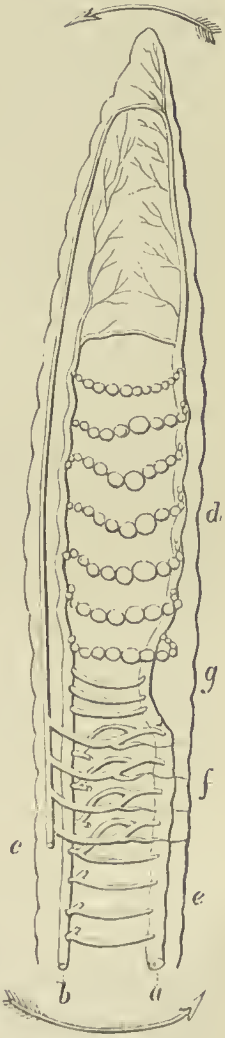
Fig. 111.



Viscera of the Earthworm.

taneous surface is the scene of a dense plexus of blood-proper vessels. It is always enveloped in a stratum of viscid fluid, which is remarkable for the property of absorbing and *dissolving* atmospheric air. This air, brought thus into immediate and intimate contact with the surface of the body, operates directly upon the blood-proper circulating in the cutaneous plexus. In the Abranchiate Annelids, as in many of the Tubicola, the alimentary canal is always profusely supplied with a vascular tissue which shares in the respiratory process, and may be regarded as a species of intestinal respiration.

Fig. 112.



Circulation in the Earthworm.

(600.) The circulation of the blood in the terricolous Annelidans has been the subject of much discussion, and until recently was but very imperfectly understood. In the Earthworm there are three principal trunks connected with the vascular system*, the arrangement of which is represented in the annexed diagram (fig. 112). First, a *dorsal vessel* (*a*) runs along the whole length of the back, in close contact with the intestine (fig. 111, *o o*), upon which it lies; this vessel is tortuous, and exhibits constant movements of contraction and dilatation, whereby the blood is propelled in continuous undulations from the tail towards the head. Two other large vessels occupy the ventral region of the body: of these, one (fig. 112, *b*), which we shall call the *ventral vessel*, runs immediately beneath the alimentary tube, while the other, that is situated close under the skin, and consequently beneath the ventral chain of ganglia composing the nervous system, by which it is separated from the last, may be distinguished as the *sub-ganglionic vessel*. These three great trunks are united by important branches, and form two distinct systems,—one of which is deeply seated, being distributed to internal viscera; the other is superficial, giving off innumerable vessels to the integuments of the body, and these, by ramifying through the skin, form an extensive vascular surface adapted to respiration.

(601.) The ventral vessel (*b*), like the dorsal (*a*), may be traced quite to the anterior extremity of the worm, where numerous small anastomosing branches unite the two trunks; but these inosculations are of little consequence in describing the circular movement of the blood,—a more important communication being established, through which the blood passes freely from one to the other, by the intervention of seven or eight pairs of large canals, situated in the immediate neighbourhood of the generative apparatus, with which indeed they are interwoven. Each of these voluminous vessels (*d*) is composed of a series of swellings, or rounded bead-like vesicles, endowed with considerable contractile power; and they form together a kind of heart, of remarkable construction, which propels the blood received from the dorsal trunk into the ventral tube (*b*)*.

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* M. Dugès, Ann. des Sci. Nat. vol. xv.

(602.) Along the rest of the body, the communication between the dorsal and ventral trunks is repeated at each ring by canals, which are much smaller than the bead-like or *moniliform* vessels, and have no vesicular arrangement; they (fig. 112, *g* and *e*) run perpendicularly upwards, embracing the alimentary canal, and giving off branches at right angles, which divide into innumerable ramifications, so as to cover the whole intestine with a delicate vascular network; these may be called the *deep-seated abdomino-dorsal branches.*

(603.) The *sub-ganglionic* vessel (*c*) may be looked upon as arising from the termination of the dorsal vessel, with which it is evidently continuous at the anterior extremity of the body. At the posterior edge of every segment a delicate branch is given off from this sub-ganglionic tube (*f*), which, running upwards in the same manner as those derived from the *ventral* trunk, joins the dorsal, and receives in its course a large anastomosing branch from the *deep abdomino-dorsal canal* that corresponds to it. From this system of superficial vessels arises a cutaneous network, which traverses the skin in all directions.

(604.) Let us now trace the blood in its circulation through this elaborate system. In the dorsal vessel (*a*) the sanguineous fluid passes from the tail towards the head; at the anterior extremity of the body it passes partly into the sub-ganglionic vessel (*c*), through the anastomosing branches, and partly into the ventral vessel (*b*), into which it is forcibly driven by the contractions of the moniliform canals. In both the ventral and sub-ganglionic trunks, therefore, the course of the blood is necessarily from the head towards the tail; and the circulating fluid is continually returned to the dorsal canal by the deep and superficial abdomino-dorsal vessels (*e*, *f*, *g*), completing the vascular circle.

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* The moniliform character which these vessels exhibit is produced by the process of dissection. If, in the ordinary way, a longitudinal dorsal incision is made, and the two halves be then separated and pinned down, the vessels under such tension are sure to assume a moniliform outline, that is, one part will dilate and the other contract, and so on successively throughout the whole length of the vessels: the dilated portion will be filled with blood, and the contracted will be empty, and the beaded figure will be perfect. If, however, a more careful mode of opening the worm be adopted, dividing, by means of fine scissors, the membranous segmental partitions, and laying gently open the integuments, these vessels will present a perfectly smooth outline; if, now, one of them be seized with the forceps and slightly pulled, it will become irregularly knotted, or moniliform. Muscular fibres, chiefly circular, are present in their parietes, and it is to the uneven action of these elements that the beaded form is attributable.—Dr. Williams.

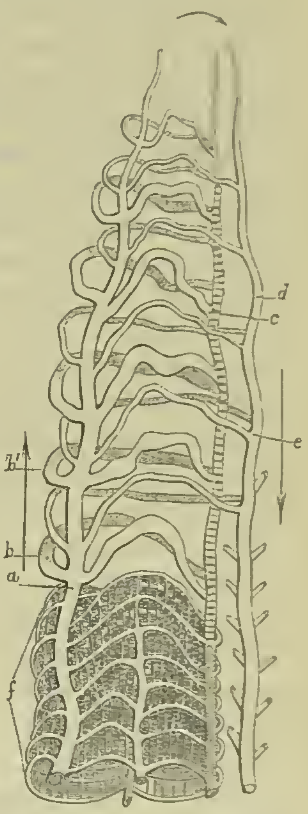
(605.) On reviewing the above arrangement, we immediately perceive that, notwithstanding the similarity observable in the distribution of the ventral and sub-ganglionic systems of vessels, in a physiological point of view they are subservient to very different functions—the former representing the systemic, the latter the pulmonary circulation. The blood derived from the dorsal trunk by the moniliform hearts (*d*) is supplied by the ventral vessel (which may be compared to an aorta), over the surface of the viscera; and the remnant of this blood, after furnishing materials for nutrition, is returned to the dorsal canal by the deep vessels (*e*, *g*); but that portion of the circulating fluid which passes from the termination of the *dorsal* tube into the *sub-ganglionic* trunk not only serves for the nourishment of the skin and muscular integument, but at the same time is brought in contact with the air as it passes through the cutaneous network, and is thus more or less replenished with oxygen before it is again returned to the general circulation. The sub-ganglionic canal is therefore a kind of pulmonary artery, and the dorsal drives to the moniliform vessels a mixed fluid, composed partly of venous blood derived from the viscera, and partly of arterial derived from the superficial or sub-cutaneous system.

(606.) Consequently in the *Lumbrici* the primary longitudinal trunks are similar in number and disposition to those of the Leech, and the direction of the blood-current is almost the same. The intestine in the Earthworm (in this respect distinguished from the Leech) is only tied to the integuments at the interannular points, the intervals or segmental spaces being left as chambers (fig. 111, *v v*) containing a small quantity of viscid corpusculated fluid, which is the peritoneal fluid of this worm. The interposition of a fluid stratum in this part involves other anatomical modifications, which still further separate the organization of the Earthworm from that of the Leech; the spongy vessels described above as occupying this part in the latter are absent in the former.

(607.) Superadded to the primary median blood-channels (fig. 113, *a*, *b*, *c*, *d*), a minor lateral system, founded upon the latero-abdominal trunk, may be demonstrated in the Earthworm as in the Leech: in all essential particulars, in the two cases, the main trunk of the system and its branches are the same.

(608.) Few points connected with the history of the Earthworms have given rise to so much speculation as the manner of their reproduction. The generative organs have long been known to be lodged in the anterior part of the body, their position being indicated externally by a considerable enlargement or swelling that extends from the seventh to about the fourteenth segment, counting from that in which the mouth is situated. On opening this portion of the animal, a variable number of white masses are found, attached to the sides of the crop and gizzard (fig. 111, *h h h*); these have long, by general consent, been looked upon as forming the reproductive system—some having been regarded as representing the testes, others the ovaria: yet so delicate are the connexions which unite these glandular masses, and such the difficulty of tracing the ducts whereby they communicate with the exterior of the body, that the functions to which they are individually appropriated have given rise to much discussion. The *Lumbrici* have been generally acknowledged to be hermaphrodite, that is, possessed of organs adapted both to the formation and fertilization of ova; and it is likewise well understood that the congress of two individuals is essential to the fecundity of both, as, in the earlier summer months, the mode in which they copulate is a matter of constant observation. At such times two of these animals are found to come partially out of the ground from contiguous holes, and, applying together those segments of their bodies in which the generative glands are situated, are observed to remain for a considerable time in contact, joined to each other by a quantity of frothy spume which is poured out in the neighbourhood of the sexual swellings. No organs of intromission, however, have ever been distinguished; neither, until recently, had the canals communicating between the sexual orifices and the testicular or ovarian masses been satisfactorily traced; so that Sir Everard Home[*] was induced to believe that, in the kind of intercourse above alluded to, there was no transmission of impregnating fluid from one animal to the other, but that the excitement produced by mutual contact caused both the ovaria and testes to burst, so that the ova escaping into the cells of the body became there mingled with the spermatic secretion, and being thus fertilized, were hatched internally, and the young, having been retained for some time in the cells between the intestine and the skin, were ultimately ejected through apertures supposed to exist in the vicinity of the tail.

Fig. 113.



Plan of the circulation in an Earthworm. (After Dr. Williams.)

(609.) According to M. Dugès[†], the arrangement of the sexual parts is represented in the diagram, fig. 114. The testicles (*b*) are placed in successive segments of the body from the seventh backwards; they vary in number in different individuals, from two to seven; but whether this variety depends upon a difference of species, or is only caused by the posterior pairs becoming atrophied when not in use, is undetermined. Each testis is fixed to the bottom of the ring in which it is placed by a short tubular pedicle that opens externally by a very minute pore, through which a milky fluid can be squeezed. The testicular vesicles of the same side of the body all communicate by a common canal; and the contained fluid, which, like the seminal secretion of other animals, contains spermatozoids, can readily be made to pass from one to another.

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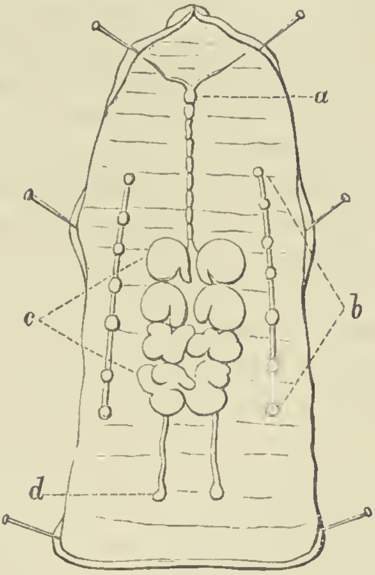
[*] Lectures on Comp. Anat. vol. iii.

[†] Ann. des Sci. Nat. vol. xv.

(610.) The ovaria (*c*) are eight large white masses, of a granular texture, from which arise two delicate tubes or oviducts; these have no connexion with the testes, but, running backwards, they become dilated into two small vesicles at their termination (*d*), and open by two apertures or vulvæ seen externally upon the sixteenth segment of the body: in these ducts, eggs have been detected as large as pins' heads.

Fig. 114.



Arrangement of the sexual organs in an Earthworm. (After Dugès.)

The following is Dr. Williams's account of this mysterious apparatus*:—

(611.) The generative system of the Earthworm is situated in the immediate vicinity of a thickened ring or band, bounded by abrupt limits, which implicates six or eight of the annuli of the body. This thickening, when closely examined, is found to depend upon an extraordinary development of the cutaneous follicles. On the abdominal aspect of this thickened portion suctorial cups are formed, by aid of which, during the congress of two individuals, mutual contact is maintained; but the generative segments internally have no relation with this suctorial ring of integument, nor has this latter part anything to do with the true genitalia. It is, like the thumb of the Frog, a mere provision for the mutual apposition of two individuals. The enlarged follicles of this cutaneous ring, moreover, discharge another function—they supply the peculiar glutinous secretion which affords a protecting capsule to the ova as they escape from the body.

(612.) Every ring in the body of this worm (except a few at the head and tail) contains two 'segment organs,' one on either side of the intes-

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* Phil. Trans. 1858.

tine; they are convoluted and tubular, arising from the ventral aspect of the general cavity near the median line, curving upward around the intestine, and terminating in a fan-shaped ciliated extremity, which is bridled to the septum near its dorsalmost edge. Those segmental organs which are situated anterior to the gizzard are very much larger and more distinct than those that are placed behind it.

(613.) The season of the year and the state of the weather have much to do with the condition in which these organs are found. All the specimens upon which the following examinations were instituted were taken in the months of July and August, from a rich, loamy, highly cultivated garden soil. This fact it is material to know, since nowhere in the ordinary fields and meadows does this worm attain the same size and plumpness. The generative *nisus* does not seem to reach its climax until the worm has arrived at a certain period of age and fulness of growth, so that, out of a hundred specimens, only ten or fifteen may be found in that condition which is required for the successful prosecution of these researches.

(614.) In *Lumbricus terrestris*, each ring of the body is divided from the adjacent ones by membranous partitions, which either completely or partially isolate the fluid contents of each annular space. It is probable, however, that the fluid of the general cavity freely oscillates from one extremity of the body to the other, through perforations in the septa. But whether the spaces be isolated or not, the 'segmental organs' which they contain have no connexion whatever with one another. The following account is descriptive of all those which are situated posteriorly to the proventriculus and the generative region.

(615.) The tube which connects the free extremity with the fixed end is extremely convoluted, and thickly intermixed with vessels. This intermediate tube is divisible into three distinct portions. First, a smooth-walled membranous part, which extends from the umbrella-like termination to the camerated or cellular portion, which is vigorously ciliated in its interior. The ciliary current sets from the free end. in the direction of the fixed end. The next division of the tube extends from the termination of the smooth membranous part to the commencement of the third stage: this portion is not ciliated: the walls bulge out into lateral cells. The segmental organ in this portion is inextricably blended and matted up with blood-vessels. The fourth division of the tube stretches from the end of the celled portion to the commencement of the muscular part: this again is strongly ciliated: its walls are thick and contractile. The last, outermost, or dilated portion. bounded externally by the attached end. is almost invariably, in the months of July, August and September, crowded with the ova and young of a Nematoid Entozoon, which might easily be mistaken for the ova and young of the Earthworm,—an error into which Dr. Williams himself fell during his earlier researches. This dilated muscular portion of the segmental organ is not ciliated internally, but its walls are capable of contracting vermicularly or peristaltically.

(616.) The vascular system in connexion with this apparatus is at certain seasons extraordinarily developed. When present under the most evident circumstances, it may be described as consisting of three parts. First, of two or three large vessels, which curve upwards from the ventral to the dorsal trunks. These vessels thus form a framework by which the slender ciliated tube is held vertically *in situ*, they themselves being vertically disposed.

(617.) Between the primary vertical trunks extend a vast multitude of secondary branches, which further subdivide to form a dense plexus of smaller vessels, in the meshes of which the ciliated tube is entangled. At certain seasons and conditions of growth, a dense mass of florid blood is attracted to and retained in the region of the segmental organs. It is contained at these times, not in ordinary cylindrical vessels, but in capacious lateral cæcal branches, terminating in large, bulbous, pear-shaped extremities, evidently constituting a special provision, the nature of which still remains a matter of conjecture.

(618.) The *sexual system* of the Earthworm we have already found to be centred in a particular region of the body, indicated by the thickened glandular collar above alluded to, which, however, on close examination, is found to be situated several segments posterior to the generative masses contained within.

(619.) Now, in studying the visceral contents of each ring within the limits of the generative region, it will be best to proceed from behind forwards. The dissector thus comes first upon the largest and most prominent of all the generative masses. They are testes, as may be proved by a microscopic examination of their contents. They have a white, glittering, oily colour. In figure they are intestiniform, the coils, of which there are two or three, being tied together by a kind of mesentery and enclosed in a membranous capsule. These two testicular masses, which lie across and fill up several rings, may be traced with perfect clearness to comparatively narrow peduncles, which, when minutely and successfully dissected, will be found to connect themselves intimately with the roots of the ciliated tubes or *special* segmental organs of the same annular spaces; or, in other words, the tube and the peduncle of the testicular mass have a common outlet. This outlet cannot be detected on the external surface of the worm; it is far too minute and closely contracted; but its position may be clearly ascertained by the termination, internally, of the ciliated tube, proving, according to the views of Dr. Williams, that the generative gland is an outgrowth from, and organically the development of the 'segmental organ.' The two ciliated tubes, one on either side, which are contained in this testicular ring, differ in no respect from those of the non-generative rings but in that of size. They are considerably larger than the latter.

(620.) The second generative annulus in the order mentioned is exclusively ovarian, and it is not difficult to see that the mass and the base of the ciliated tube run together, and become blended into one structure. The most minute dissection fails to isolate the duct which, it may be supposed, leads from the ovary; but, as in the case of the testes behind, it is certain that the gland and the tube must have a common outlet. The ovary is considerably smaller than the testes; its capsule is more dense and vascular, and its interior structure is much more copiously supplied with blood.

(621.) In the common Earthworm the second, third, and fourth generative segments are ovarian, each being anatomically only a repetition of the other; all are constructed upon the same plan.

(622.) The fifth segment, from behind, is again testicular, exactly resembling the first, so that the first and the last segments in this region are testicular, the three intermediate ones being ovarian.

(623.) The ovaria of *Lumbricus* are much more transient in their duration than the testes; the latter, in a certain condition, are always present at every season of the year, the former only in the summer months. The ova, while yet in the ovaria, are beautifully clear transparent cells. In August and September they seem to consist of nothing but germinal vesicles; afterwards appear the germinal *spots*, and then the rudimentary vitellus. At a subsequent stage, just before their extrusion from the body, they become covered with a cocoon or characteristic capsule, each capsule containing many ova. This capsule is a compound of chalk and mucus. In the median line between the ovaria there are situated two or more glandular bodies, the contents of which, under the microscope, are found to consist of nothing but carbonate of lime—doubtless the source of the chalk.

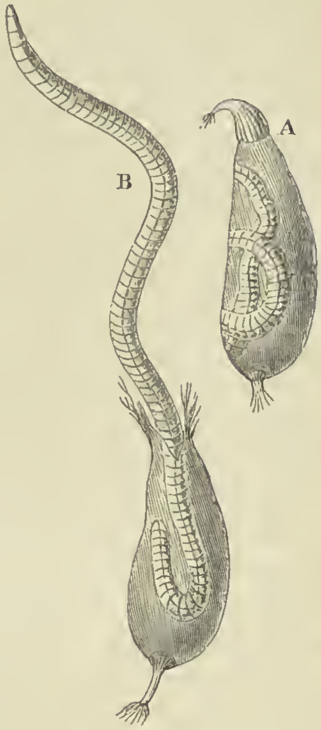
(624.) Both in the ovarian and testicular segments there are sacculi attached to the bases of the segmental organs, which in the former case serve as receptacles for the ova (*vitellaria*), and in the latter as receptacles for the semen. In one case the ova acquire their calcareous capsules; in the other the sperm-cells become developed into active spermatozoa.

(625.) The eggs, when laid, are said by Dugès to be two or three lines in length. In fig. 115, A, one of them, enclosing a mature embryo, is delineated; its top is seen to be closed by a peculiar valve-like structure adapted to facilitate the escape of the worm, and opening (fig. 115, B) to permit its egress. Another remarkable circumstance observable in these eggs is that they very generally contain double yelks, and consequently two germs; so that a couple of young ones are produced from each.

(626.) It is very generally believed that the Earthworm may be multiplied by mechanical section, the separated portions reproducing such parts as are removed in the experiment, and again becoming perfect.

Careful experiments, made to ascertain how far the statements of former authors upon this subject might be substantiated, prove that the assertion is not entirely without foundation, although by no means to the extent indicated in their writings. It would, indeed, be easily credited that the removal of the hinder part of the body of an Earthworm would not necessarily destroy the anterior portion, since no organs absolutely essential to existence are removed by the operation, and even the course of the circulating fluids would not be materially interrupted by the mutilation; but that the hinder moiety should be able to reproduce the mouth, gizzard, and stomach, the complicated apparatus of moniliform vessels, and the sexual organs, contained in the anterior segments, could scarcely be deemed possible; and the assertion has been satisfactorily disproved by actual observation. On cutting an Earthworm in two, the anterior portion is found, in fact, generally to survive; and the wound caused by the operation, becoming gradually constricted, is soon converted into an anal orifice, rendering the animal again complete in all parts necessary for its existence. This, however, is by no means the case with the posterior portion; for, although it will exhibit for a very long period indications of vitality, no signs of reproduction have been witnessed, and it invariably perishes.

Fig. 115.



Eggs of the Earthworm.

(627.) Nevertheless, although it is thus proved that the Earthworm cannot be multiplied by mechanical division, it is stated to be able to reproduce small portions of its body the removal of which does not implicate organs essential to life. In the experiments of M. Dugès, for example, it was found that four, or even eight of the anterior rings might be cut off with impunity, although the cephalic pair of ganglia, the mouth, and a part of the œsophagus were necessarily taken away. In worms thus mutilated, after the lapse of from ten to thirty days a conical vascular protuberance was observed to sprout from the bottom of the wound; and in eight or ten days later this new part had become so far developed, that not only all the lost rings were apparent, but even the upper lip and mouth had assumed their normal form, and the animal again began to eat and bury itself in the earth.

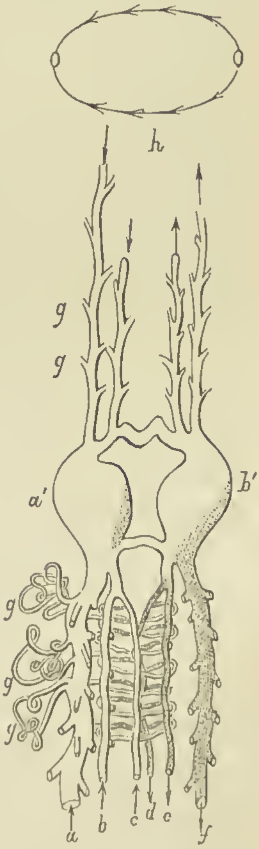
(628.) The experiment of artificially bisecting the body of an Earthworm, replacing the divided halves with care again in their native habitats, invariably, in the hands of Dr. Williams, led to the following results:—The *cephalic half*, by this division of the body, does not lose the power of locomotion. In a few days after the operation, it begins to grow less active and vigorous in its movements, and the annulus at the point of division begins to contract and wither; in the course of a few more hours it dies—it mortifies away. This process of dissolution creeps, in the direction of the head, from one segmental ring of the body to another, until, finally, the cephalic remnant ceases to manifest any signs of life.

(629.) The tail-half immediately loses the power of advancing; it writhes on one spot, and that only in contact with some external body; its motions become *excited*, not *voluntary*; it never re-acquires the power of swallowing earth. The process of decay begins much sooner than in the cephalic half, and extends in the direction of the tail, implicating one ring after another rapidly, until the whole perishes.

(630.) The little lively *Naides*, although terricolous in their habits like the Earthworm, are very dissimilar in organization.

(631.) In *Nais filiformis*, so abundant in the freshwater pools of this country, the anatomist is presented with a favourable opportunity of resolving the problem of the circulation. A living specimen placed between two slips of glass, from the perfect transparency of the integuments, will exhibit to the eye in a perfect manner all the circulating movements both of the vessels and of the blood. In *Nais*, the large dorsal vessel (fig. 116, *a*) is first seen travelling wavingly along the dorsum of the intestine as far as the heart, which corresponds in situation with the intestinal end of the œsophagus. This vessel is enveloped by the glandular peritoneal layer of the intestine, while the coats of the ventral vessel are clear and transparent: the dorsal vessel is endowed with parietes of greater strength and density than the ventral. Each of these vessels dilates into a fusiform heart (fig. 116, *a'*, *b'*), situated on either side of the œsophagus. These hearts, which are joined together by transverse vessels, pulsate *alternately* and with exact regularity. In the dorsal vessel the blood moves forwards from the tail as far as the dorsal heart; thence it descends into the ventral heart, by which it is now propelled, chiefly in a backward direction, partly through the main ventral trunk, and partly through the inferior intestinal. The other portion of the blood conveyed by the great dorsal vessel into the ventral heart (*b'*) passes forwards as far as the head, where its moving power is again reinforced by a cardiac dilatation, which now impels the current from before backwards through a superior œsophageal trunk into the dorsal heart (*a'*), by which organ the blood received from the region of the œsophagus and coming from the head, as well as that received from the great dorsal and coming from the tail, is urged downwards into the ventral heart, and thence, chiefly in the direction of the tail, through the ventral and intestinal trunks (*f*, *e*); this latter therefore is the true systemic heart. At the œsophageal end of the body, the two primary trunks, dorsal and ventral, are connected together by means of a remarkable class of vessels (*g g g*), which in this region proceed at successive points from the dorsal œsophageal, and which may be traced in long coils, *without division of the vessel,* floating in the fluid of the peritoneal cavity. Posteriorly to the heart-centre these vessels emanate from the dorsal *intestinal,* and correspond precisely with those branches from the same vessel which in *Arenicola piscatorum* proceed to supply the branchial arbuscles. In *Nais,* therefore, partly from this analogy, but chiefly from their anatomical relations, bathed by and floating in the chylaqueous contents of the peritoneal cavity, the physiologist can experience no difficulty in dedicating these coiled vessels to uses very definite. First, it cannot be doubted that they absorb from this fluid the elements by which the blood-proper is formed and replenished; and secondly, it is in the strongest degree probable that the true blood is in *great part* aërated through the agency of these vessels upon the gaseous elements contained in the peritoneal fluid. They constitute the special branchial system (internal branchiæ), while they discharge incidentally an absorbent function. In the movement of the blood, then, in *Nais* as in *Lumbricus,* there are discernible only two leading directions—one forward in the primary and intestinal dorsal vessels, the other backward in the primary and intestinal ventral. It is not possible to trace the blood into the capillary parietal system of the intestine, in consequence of the transparency of the stream when thus minutely subdivided. In *Nais* there is also an integumentary system which intervenes between the two primary (dorsal and abdominal) trunks (*a*, *f*), ramifying in the substance of the integuments, upon which, in part, a respiratory function may devolve.

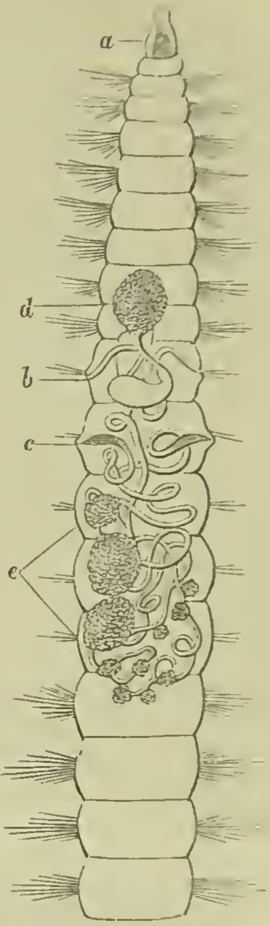
Fig. 116.



Plan of circulation in *Nais.* (After Dr. Williams.)

(632.) The generative system of the *Nais,* as delineated by Dugès, presents a very different arrangement to that which exists in the Earthworm. The swollen part of the body, in which the sexual organs are placed, occupies a space of five or six rings, beginning at the eleventh. On each side of the eleventh segment is a minute transverse slit (fig. 117, *b*) communicating with a slightly-flexuous canal which terminates in a transparent pyriform pouch or vesicle. The latter contains a clear fluid, wherein minute vermiform bodies are seen to float, and most probably represents the testis. The twelfth segment likewise exhibits two openings, each placed upon the centre of a little nipple (*c*): these are the orifices leading to the female portions of the sexual system. The ovaria (*d*, *e*) are composed of four large and several smaller masses of a granular character; and from them proceed long and tortuous oviducts, which, just before their termination at the lateral openings (*c*), become thick and glandular. These animals most likely copulate like the Earthworm, and lay their eggs in a similar manner. We have already seen, in the *Lumbricus terrestris*, ova containing two yelks, and consequently giving birth to two animals; but in the *Nais* every egg produces ten or a dozen young ones*; or perhaps we ought rather to say that what appears to be a single egg is in fact merely a capsule enclosing several distinct ova, from which a numerous progeny arises. The manner in which these compound eggs are formed is easily understood when we consider the structure of the oviduct described above. The granular germs escape, no doubt, separately from the ovaria, and remain distinct from each other as they pass along the tortuous canal that leads to the external opening; but at length arriving at the thick and glandular portion (*c*) of the ovigerous tube, several of them become enclosed in a common investment secreted by the walls of the oviduct, and are expelled from the body with the outward appearance of a simple egg.

Fig. 117.



Generative organs of *Nais*. (After Dugès.)

The account of the reproductive system of the *Naides* given by Dr. Williams† is as follows:—

(633.) In *Nais serpentina*, which may be taken as the type of the genus, two of the 'segmental organs' are present in every ring of the body, one on either side of the intestine. Each organ commences (or, if the course of the contained current be considered, *ends*) in a single external orifice. At its free internal extremity it is held in a determinate position by means of bridles of delicate threads. By the action of large and vigorous cilia, a strong current of fluid is drawn into this open mouth. From the form and structure of the trumpet-shaped extremity,

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* Dugès, Ann. des Sci. Nat. vol. xv.

† Phil. Trans. 1858.

as well as from the setting of the ciliary currents at the mouth and base of the tube, it seems beyond the possibility of a doubt that these organs, in *this ordinary* state, subserve the function of discharging externally the fluid contained in the general cavity of the body; nevertheless, from their small diameter, it would appear that they are not capable of conveying externally either the normal corpuscles of the chylaqueous fluid or the spermatic products. The preceding description applies only to the 'segmental organs' distributed throughout that part of the body of the worm which is situated behind the reproductive mass.

(634.) It now remains to investigate the claims of this organ to a new and hitherto unthought-of relation with the generative or reproductive structures; for in this worm two, or possibly more, of these segmental organs on either side of the body undergo a remarkable increase of size and variation of form.

(635.) In *Nais* it often happens that only one on either side is thus evolved. At some seasons, however, especially when the weather has continued for some time warm and dry, individuals may be found in which two on each side have undergone a marked development; generally, however, two segmental organs only, the one being developed into the male, the other into the female moiety of the reproductive system, are necessary to the generative maturity of the individual.

(636.) The two segmental organs which form the basis of the reproductive masses are observed, even on the first view, to be very similar in general outline to those which are repeated in every ring of the body, with which indeed they are identical, differing only in size and in the shape of some of their parts. The dilated portions correspond with the equivalent parts of the other organs; and the umbrella-like extremities, which are the same in form on the ovarian and testicular sides, are the counterpart of the free ciliated ends of the ordinary organs. The intermediate ciliated tubes are specially distinguished only by their greater length and thickness. It is a difficult point to settle the mode in which the generative masses are related to the ciliated tubes; it may, however, be constantly seen that the ovarian mass moves to and fro with the dilated portion of the tube. It is impossible to detect the opening by which the ova arrive in the interior of the *utriculus* of the tube; that they do get there, however, is certain. From this portion of the tube they escape by the external orifice.

(637.) The *testes* on the other side bear the same relation to the tube as the ovary. The *utriculus* upon one side is represented by the ejaculatory pouch on the other. At present it is beyond the power of science to explain why these organs, in only one or two annuli of the body, should be implicated in the sexual development, while all the rest remain in abeyance in the condition of mere 'excretionary tubes'; or why the ciliated tube of one side should be changed into the female system, and that of the other into the male.

(638.) Besides the ordinary mode of propagation by ova, it has long been asserted that some of the Annelida, at least, are reproduced by spontaneous division. Bonnet, Müller, and Dugès all agree that this is the case with certain species of *Nais*; and in *Nais filiformis* the process of separation has been witnessed from its commencement to its termination. The division was said to occur near the middle of the body of the animal, the posterior half remaining motionless upon the mud of the bottom of the vessel, whilst the anterior portion buried itself as usual: after some days the truncated extremity of the hinder part was observed to become swollen, transparent, and vascular, and ultimately to assume the complete structure of the mouth of the perfect animal; it then buried itself in the mud, and no doubt there completed its development.

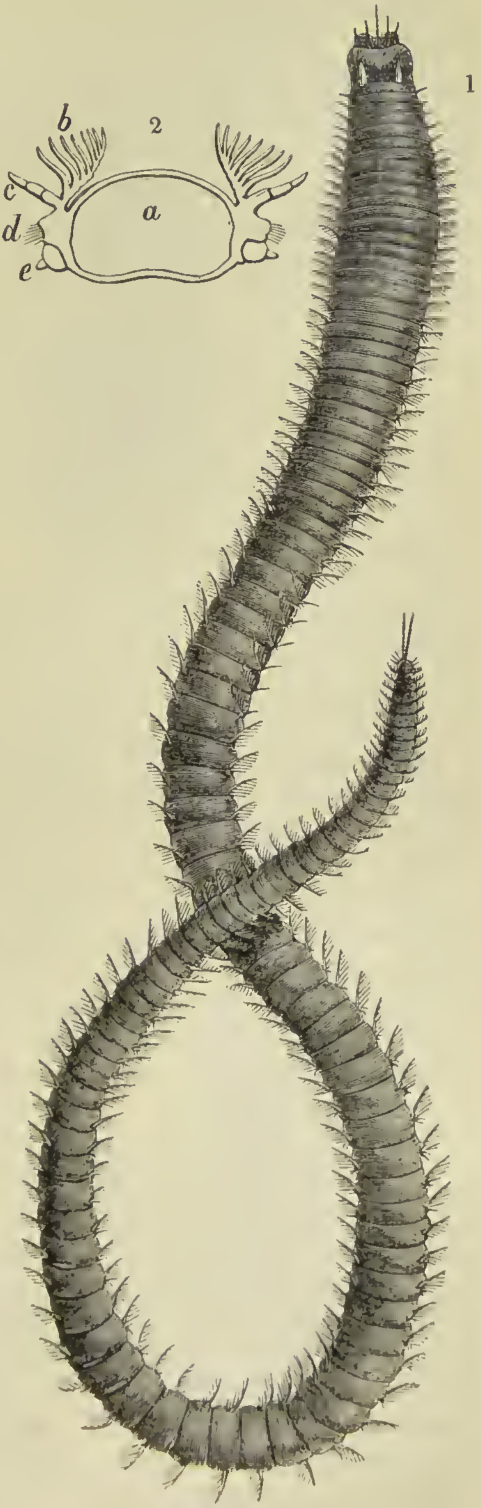
The following is what Dr. Williams conceives to be the interpretation of the above facts:—

(639.) Every *Nais*, as relates to its reproductive apparatus, is identically constituted, and this worm is consequently androgynous. *Every individual*, towards the latter end of the summer, dies by the bisection of its body. It is not true, as reported by Dugès, and before him by Spallanzani, that the fragments into which the body of each worm becomes resolved are again reconstructed into a perfect whole. Although the sexual system exhibits a tendency to segmental repetition, there devolves upon the large anterior portion, described by Dugès, a special function which the rest cannot perform; and, on the contrary, a duty falls on the posterior segmental units of the system which the anterior cannot discharge. It is consequently evident that neither of the moieties into which the body is resolved during the crisis of the reproductive season can be organically perfect. Such fragmentary organism is wanting in elements paramountly essential to individuality.

(640.) These Annelids are *annuals*: the term of existence is completed when the organic cycle is *once* accomplished. They are born during the latter months of one summer, and survive the winter, attain to the maturity of growth, reproduce the species, and die by the spontaneous subdivision of the body into fragments on the arrival of the same season of the succeeding year. This brief round comprehends the history of each individual. Since these worms are monœcious, each shares the common fate. Each contributes by its own death to the multiplication of the species: the species being multiplied, the ends of its own existence are accomplished.

(641.) For some time before the fissure of the body occurs, the process of the maturation of the ova is proceeding. Arrived at the matured phase, they escape from the ovarian system into the free space of the peritoneal cavity, wherein they sojourn until the next phase of their growth has been attained. It is during the period marked by the presence of true ova in the chamber of the peritoneum, floating in the contained fluid, that the division of the body of the parent animal takes place. In each fragment is therefore incubated a considerable number of ova. Filled still by the fluid of the peritoneal cavity, each fragment becomes subservient to the end of hatching the young. It resists decomposition only during the period required for the accomplishment of this purpose. When the ova are committed to the sand, the fragment rapidly disappears by putrefaction. The fissure of the body, thus interpreted, becomes the last act of the parental worm, since the portions into which the body is subdivided by fissure *never take food.* With the fissure the necessity for food terminates. If, on the contrary, the division of the body were the first step of a real reproductive operation, characterized by the superaddition of new segments to the body, each fragment *should* grow voracious and consume extra supplies of nourishment in order to provide the necessary pabulum for the reparation of mutilated parts. As this is not the fact, the inference is clear that the division of the body is not the prelude to a series of reconstructive operations by which *parts* are made "*wholes,*" or mutilations repaired.

Fig. 118.



Laodicea antennata.

(642.) Dorsibranchiata.—In the second order of the Annelidans the respiratory apparatus consists of numerous vascular tufts, a pair of which are appended to the outer surface of every ring of the body, or, in some cases, only to a few of them. The organs of locomotion, which are attached to each segment, assume various forms, but are generally composed of short moveable spines, or packets of retractile bristles, usually destined to perform the office of oars. In the annexed figure (fig. 118, 1), which represents *Laodicea antennata*, the general form of these animals is well seen, as is the most usual arrangement of the branchial tufts and locomotive setæ. In fig. 118, 2, showing an imaginary transverse section of one of the segments, the relative positions of the oars (*c*, *d*, *e*) and of the branchial appendages (*b*) are likewise indicated.

(643.) But the organs of respiration in the Dorsibranchiate Annelidans are not always arborescent; on the contrary, they are not unfrequently spread out into thin membranous lamellæ, or resemble fleshy crests or vascular tubercles: still, whatever their form, their office is the same; and the vessels spread over them presenting an extensive surface with which the water is brought in contact, the blood is oxygenated as it passes through them.

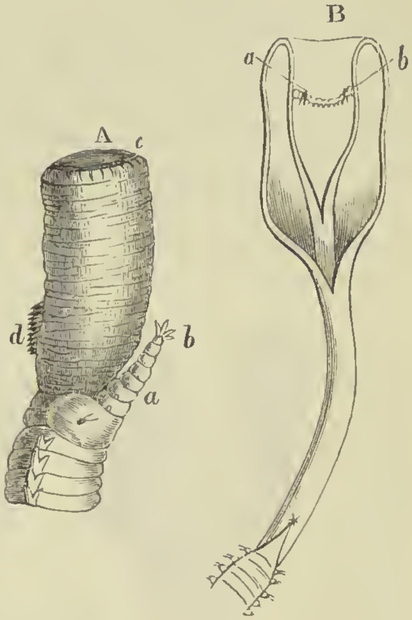
(644.) The second class of organs to be enumerated as entering into the composition of the lateral appendages are soft, fleshy, and subarticulated processes called *cirri* (fig. 118, 2, *c*, *e*); these are generally two in number, and belong one to the ventral and the other to the dorsal oar: their precise office is not well understood; but as in some of the segments, especially in the neighbourhood of the head, they assume a tentacular form, they have, with much probability, been regarded as instruments of touch.

(645.) The *setæ* (fig. 118, 2, *d*) are, perhaps, the most efficient agents in progression. These are long and stiff hairs disposed in bundles and implanted into strong muscular sheaths. Each packet of setæ can be retracted within the body to a certain extent, and again protruded by the action of the tubular supports from which they arise: and being capable of independent action, these organs must be looked upon as so many powerful fins, well calculated to propel the creature through the element it inhabits.

(646.) The structure of the mouth in the Dorsibranchiate Annelidans is very peculiar. The first portion of the alimentary canal, or stomach, as it is most erroneously called by some writers, is muscular; and certainly, when seen in a dead Annelid, it might easily be taken for a digestive cavity. Nevertheless, during life, this part of the alimentary apparatus is destined to a widely-different office; for it is so constructed that, at the will of the animal, it can be completely everted, turned inside out, and, when thus protruded externally, it forms a very singular proboscis, used in seizing food, and frequently armed with powerful teeth of singular construction. The following figure (119, A), representing the head of one of these worms (*Goniada à chevrons*, Milne-

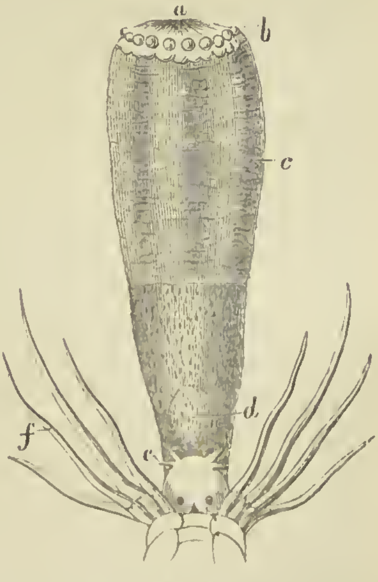
Edwards), will give a good idea of this curious organ when fully displayed: and in fig. 119, B, the mechanism is exhibited by which its protrusion and retraction are accomplished. The whole apparatus is there seen to consist of two muscular cylinders, placed one within the other, but continuous at their upper margin (B); or, to use a familiar illustration, the proboscis may be compared to the finger of a glove partially inverted. It is obvious that, in this case, if the inner cylinder be drawn inwards—that is, into the mouth,—the whole structure becomes shortened, until at last it is entirely retracted into the oral cavity; whereas, on the contrary, if the outer tube is made to protrude, it expands at the expense of the inner one, which is gradually drawn forwards. The internal surface of this remarkable proboscis, moreover, is variously modified in its structure, so as to adapt it to the prehension of different kinds of prey. In *Amphinome*, for instance, the orifice of the mouth is a thick, fleshy, and callous circle (fig. 122, *b*, *c*, *d*), and the surface of the exserted proboscis (*c*, *d*) is covered with delicate transverse rugæ, evidently so arranged as to give tenacity to its gripe. In *Goniada* it supports two distinct sets of horny teeth, provided for very different uses: one set, which is exposed when the proboscis is unrolled to a very small extent, consists of a series of linear horny plates (fig. 119, A, *d*), and probably forms a kind of file, or rather a scraper, wherewith the animal excavates the subterranean galleries in which it lives. The other set does not make its appearance till the proboscis is more completely expanded, and is evidently an instrument of pre-

Fig. 119.



Mouth of *Goniada clavigera*.

Fig. 120.



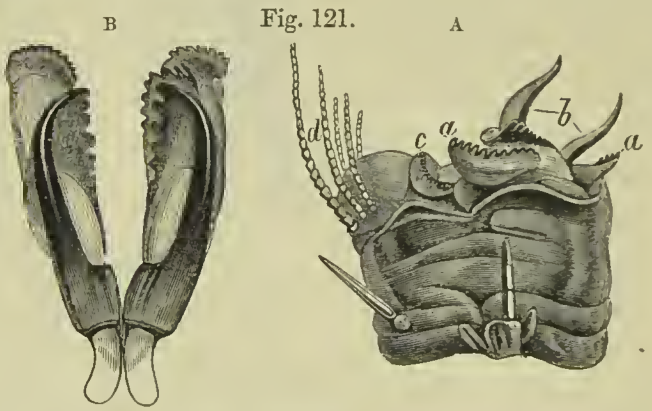
Mouth of *Phyllodoce laminosa*.

hension, formed by two horny hooks (fig. 119, B, *a*, *b*) placed upon an elevated ridge near the entrance of the œsophagus, so as to take a secure hold of any victim seized by this curious mouth.

(647.) In *Phyllodoce laminosa* the teeth form a circle of semicartilaginous beads encompassing the extremity of the proboscis when that organ is pushed out to its full length (fig. 120, *b*),—an arrangement well adapted to hold and, perhaps, to crush their prey.

(648.) But the most formidable jaws are met with in some of the Nereidiform species, as in *Laodicea antennata*, of which a figure is given above (fig. 118). When the proboscis of one of these creatures is slightly everted, the extremities of three pairs of strong horny plates emerge from the mouth: of these, one pair terminates by forming a powerful hooked forceps, while the others present strong denticulated margins (fig. 121, A, *a*, *b*, *c*). The nature of these teeth will be better seen by a glance at B in the same figure, where they are represented. upon an enlarged scale, as they appear when detached from their connexions.

Fig. 121.



Jaws of *Laodicea antennata*.

(649.) The alimentary canal of the Dorsibranchiate Annelidans offers little which requires special notice. It invariably passes in a direct line from the termination of the proboscis to the anal extremity of the body. In the *Nereidæ* it is provided with numerous lateral pouches, somewhat resembling those of the Leech. In *Aphrodite* these lateral cæca are very long, slender, and branched at their extremities, so that they have been thought by some to be secreting organs, representing the liver. In *Arenicola* we find, at the termination of the œsophagus (fig. 128, *f*), two large cæcal appendages (*e*), of unknown office, while the rest of the tube (*c*) is entirely covered with minute sacculi, the walls of which are decidedly glandular and secrete a fluid of a greenish-yellow colour.

(650.) In the majority of the Annelids, observes Dr. Williams, the alimentary system constitutes a cylindrical tube, which bears a general resemblance of outline to the integumentary,—this latter forming, with respect to the former, an exterior concentric or embracing cylinder. These two cylinders are in no instance in agglutinated contact: a space intervenes, varying in capacity in different species, to designate which the term 'peritoneal,' or splanchnic, may be used with perfect propriety. This space is occupied by a vital or organized fluid charged with corpuscles, which exhibit, under the microscope, characters distinctive of species. Independently of its physiological uses, this fluid enacts mechanical functions indispensable to the well-being of the animal: on it, as upon a pivot, the vermicular motions of the intestinal cylinder are performed.

(651.) Although, as a whole, forming a cylinder, in no instance does the alimentary canal of the Annelida present the figure of a smooth-walled tube. The parietes are invariably sacculated, and often superficially multiplied in the most elaborate manner. In the Lumbriciform species, each segment of the body has its own independent stomach. Those of contiguous segments communicate through an opening considerably more contracted in diameter than that portion of the intestine from which it leads. Thus the intestine of the Errant Annelids, especially, may be compared to a line of pears, the apex of each successive pear being applied to the base of its predecessor in the series: if these bases were prolonged on each side, the stomach of the Leech would be the result; if compressed, that of those species in which the tube is nearly straight.

(652.) The course of the principal trunks of the circulating system in the Dorsibranchiata bears a general resemblance to what we have already seen in the Abranchiate order, modified, of course, by the variable position of the branchial tufts. The annexed figure (122) of an elaborate dissection of an Amphinome (*A. capillata*), copied from one of the beautiful drawings contained in the Hunterian Collection*, affords an example of a circulating system in which the propulsion of the blood is effected entirely by vessels, without the intervention of any muscular cavities or heart. In this animal the respiratory organs are penniform appendages placed along the back, and these external vascular tufts communicate with delicate plexuses of vessels, situated in the interior of the body, called the branchial plexuses. In the figure the branchial plexuses of the left side only are represented (*q q q*); and of these, one marked *q'* has been turned aside. The blood and nutritious fluids derived from the whole alimentary track are collected by the large ventral intestinal vein (*n n n*) and conveyed to the branchial plexuses through the numerous vessels (*o o o*), some of which (*o' o' o'*) are displaced in the drawing in order that their connexions may be better seen. Besides the blood and nutriment thus derived from the intestine, the branchial plexuses receive the circulating fluid from all

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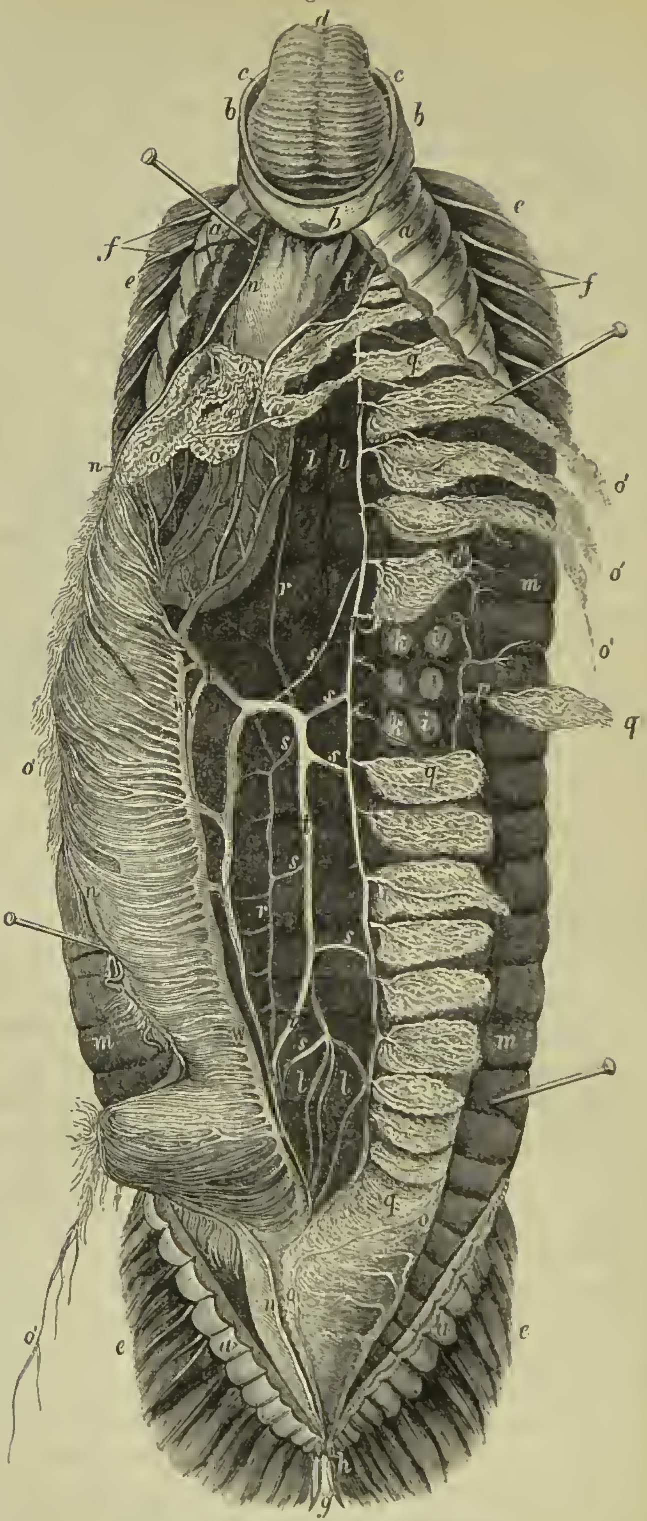
* Descriptive and Illustrated Catalogue of the Physiological Series of Comparative Anatomy in the Mus. Roy. Coll. Surg. of England, vol. ii. pl. 14.

Fig. 122.



Circulatory system of *Amphinome capillata*.

the segments of the muscular envelope by separate veins (*p p*); and thus the blood from all parts is brought to the gills and exposed to the influence of oxygen.

(653.) After undergoing respiration, the blood is collected from the branchial plexuses by the lateral veins (*r r r*), from which, through communicating vessels (*s s s*), it passes into the aorta or great dorsal vessel (*t t t*) to be distributed through the body. From the aorta large trunks (*v v*) are given off to form the intestinal artery (*w w*), which, ramifying over the intestine, communicates with the intestinal vein (*n n*) and thus completes the vascular circle*.

(654.) In *Eunice sanguinea* the circulatory apparatus consists of a short but capacious dorsal vessel (fig. 123, *l'*), which rests upon the pharyngeal portion of the digestive tube, without, however, being adherent thereunto, and communicates posteriorly with a vascular circle that surrounds the stomach and receives the blood from the intestinal parietes through two longitudinal trunks (fig. 123, *l*) situated upon the dorsal aspect of the alimentary tube.

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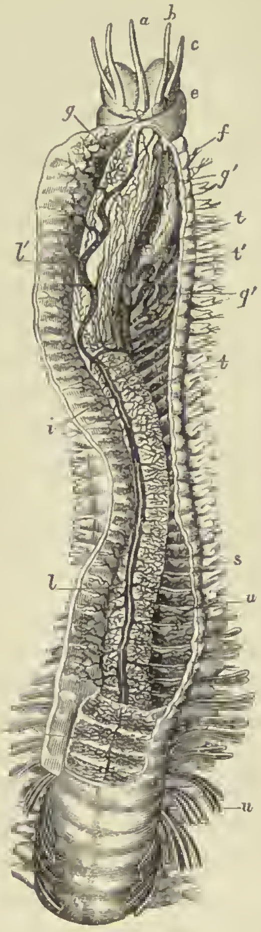
* The parts indicated in the drawing by letters not referred to in the text are the

(655.) In its course towards the head, the single dorsal vessel (*l′*), which is a continuation of the two dorso-intestinal veins (*l*), receives several branches, some derived from the digestive canal, others proceeding from the muscles and integuments of the neighbouring part of the back. These last-named branches communicate with a slender cutaneous medio-dorsal vessel that runs along the entire length of the body and receives from each segment numerous cutaneous ramusculi (*x*). Lastly, the dorsal vessel gives off from its anterior extremity various branches to the cephalic segments, as well as others which are directed outwards, as in the *Terebella* described hereafter; but these, instead of supplying branchial organs, take a backward course, and are either distributed to the parts in the vicinity of the pharynx, or their ramifications anastomose with those of the ventral vessel, immediately to be described.

(656.) The ventral vessel (fig. 123, *q′*) gives origin, opposite each segment, to a pair of lateral branches; but the conformation of these branches, as well as the functions to which they are destined, are very different. Immediately after its origin, each lateral branch becomes considerably dilated and bends back suddenly upon itself, so as to resemble, when superficially examined, an

Fig. 123.



Circulatory and respiratory apparatus of *Eunice sanguinea*: *a*, *b*, *c*, the antennæ; *e*, the first segment of the body; *f*, lateral appendages, or rudimentary feet; *g*, pharynx; *g′*, mandibular muscles; *i*, intestine; *l′*, vessel performing the functions of an aortic or systemic heart; *l*, superior intestinal vessels; *s*, their lateral branches (or branchial veins); *q′*, ventral vessel; *t*, its lateral branches; *t′*, contractile ampullæ, performing the functions of branchial hearts; *u*, branchiæ; *x*, subcutaneous vessels of the back. (After Milne-Edwards.)

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following:—*a a*, the ventral surface of the segments of the body; *c c*, the ventral oars, or packets of bristles; *f f*, the ventral cirri, or feelers; *g*, the anal cirri; *h*, the anus; *i i*, *k k*, the bases of the dorsal and ventral oars, with their surrounding muscles; *l l*, the dorsal longitudinal muscular bands; *m m*, the ventral longitudinal muscular bands.

ovoid vesicle, or ampulla; it then runs outwards, furnishing an ascending branch to the alimentary canal, and on arriving at the base of the feet, or locomotive appendages, gives off several small anastomosing branches, forming a sort of vascular network, whence vessels are supplied to the corresponding branchial filaments.

(657.) The blood, after being subjected to the influence of oxygen in the branchial appendages, is returned by other transverse vessels which run along the interannular septa to the alimentary canal, where they ultimately discharge themselves into the large median trunks (*l*) situated upon tho dorsal aspect of the intestine.

(658.) Considered generally*, it will be perceived that the distribution of the vascular trunks in the Eunices is pretty much the same as that which exists in the Terebellæ; but when their functions are considered, and the relations in which they stand relatively to the respiratory apparatus, very important differences are at once apparent between the two genera.

(659.) In *Eunice*, it will be seen (fig. 123) that Professor Milne-Edwards has described and figured the branchial vessels as ampullated soon after the origin of each from the common trunk, the ampullæ being designed to fulfil the function of branchial hearts. These vessels therefore, according to the representations of Milne-Edwards, are, in *Eunice*, the analogues of those remarkable cardiac vessels (pulmonary hearts) described by Dugès in the Leech. The existence of these latter vessels has already been found to be extremely problematical (§ 583). According to the observations of Dr. Williams, these vessels in *Eunice* present nothing approaching to the ampullæ figured in the illustrations of Milne-Edwards. The pouched dilatations are *produced* by the dissection and exposure to atmospheric stimulus, just as in the Earthworm the moniliform character of the descending vessel was shown to be caused by the *stretching*. In *Eunice* the lateral large segmental branches are relatively large at first, but soon divide into three lesser branches, of which one goes to the feet, the other to the intestine, and the third to the branchiæ, from which the blood returns into the dorsal vessel, which in this worm, accordingly, carries arterial blood. The suddenness of this division favours the imprisonment of a drop of blood in the first stage of the vessels, the drop thus enclosed occasioning a bulged enlargement; but this appearance is altogether accidental. The blood is admitted into and returned from the branchiæ by alternate movements of contraction and dilatation: these movements are not simultaneous in all the branchiæ, but various and independent in each individually, the afflux into one being synchronous with the efflux of blood from those contiguous. This contractile power is by no means peculiar to these vessels. The motion of the blood in the vessels of every part of the body of the Annelid is effected, not through the agency of uniformly-travelling undulatory contractions of their coats, but by complete contractions and relaxations of successive portions of the tube; so that, during the instant of contraction, the cylinder of the vessel in the part contracting is completely emptied of blood, the sides collapsing and meeting in the axis; and during the period of dilatation the same portion of the vessel becomes densely distended with blood: and this is the true mechanism of the circulation in those species, even, in which a central propulsive organ exists—for example, in *Nais* and *Arenicola*. In no part of the system, therefore, is the superadded contractile bulb required as an agent of circulation, since this contractile power resides in every part of *every* vessel in virtue of the muscularity of its parietes.

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* The following axioms may be laid down relative to the circulation of the blood:—

1st. In all Annelids, the blood flows in the great *dorsal* trunk from the tail towards the head.

2nd. In all Annelids, the blood flows in the great *ventral* trunk from the head towards the tail.

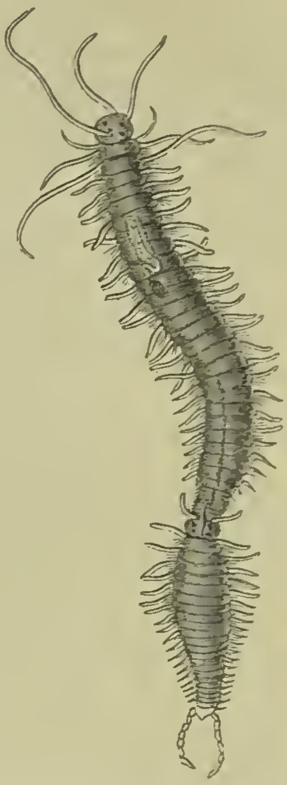
3rd. In the whole integumentary system of vessels, the blood moves from the great ventral towards the great dorsal trunk: this movement constitutes the annular, or transverse circulation. The main current of the blood in the ventral trunk pursues a longitudinal course until exhausted by successive lateral deviations.

4th. In Annelids, the intestinal system of vessels consists of four longitudinal trunks: one dorsal, which may be called dorso-intestinal; one ventral, which may be distinguished as the sub-intestinal; and two lateral. These several trunks are joined together by circularly-disposed branches bearing a dense glandular capillary system. In the inferior intestinal system the general movement of the blood is from before backwards; in the circular branches, from the ventral towards the dorsal trunk.

(660.) A general survey of the circulation in *Eunice* will suffice to satisfy the physiologist that no part of the system contains pure arterial, and no part pure venous blood. Into the double dorsal trunk arterial blood is poured from the branchiæ; but to the same trunk the intestinal branches contribute venous blood: the mingling of these two classes of currents in the same trunk must result in blood of an intermediate quality. It is, then, manifest that the great subneural trunk, which in this worm is both systemic and branchial, must distribute blood of composition intermediate between venous and arterial. No part of the circulatory apparatus therefore contains pure arterial blood except the efferent branches of the branchiæ.

(661.) In some Annelidans we still find that gemmation performs a very important part in the reproductive process: the multiplication of the individual segments of the body depends entirely upon this mode of increase. But this is not all: it not unfrequently happens that when these animals have attained their full growth, a constriction becomes apparent near the posterior extremity, immediately behind which a proboscis and eyes are developed, forming the head of a new animal subsequently to become separated by spontaneous fissure (fig. 124); and even as many as six of these strangely-formed offsets have been counted by Milne-Edwards in continuity with each other*. The process of division is represented in fig. 124: the hinder part of the body, including about seventeen segments, is seen to be gradually separated from the anterior or larger portion; and moreover, at the point of separation, a new head, with eyes and tentacular cirri, is distinctly formed. "In one case," says Müller, "I found a mother to which three fœtuses of different ages adhered in one length. The mother had thirty pedate segments: the youngest daughter, or that nearest the mother, had eleven; but the head was not yet developed. The most remote had seventeen rings, with both head and eyes, and, moreover, the tail of the mother; the middle one had seventeen segments and a head.

Fig. 124.



Gemmiparous reproduction of *Cirrhatula*.

(662.) From various observations, it would seem that similar phenomena present themselves during the development of other Annelidans; proving that the bodies of these animals grow by the successive formation of new segments, or zonules, which sprout from those already in existence, in accordance with a fundamental plan, and become arranged in regular sequence, one behind the other.

(663.) It is likewise evident that the two extreme portions of the body, namely the oral and anal segments, are first formed, and that it is in the space between these that all the segments of the trunk, however numerous, have their origin,—their development being carried on in a single series, which is progressively extended from before, backwards, by the continual addition of new segments, which are so disposed that the relative age of each ring is indicated by the position which it occupies. Each newly-formed zonule is invariably interposed between the last-developed segment and the anal ring; so that it becomes natural to inquire from which of these two it more immediately derives its origin, —a question that at first might appear of difficult solution, but which seems to be set at rest by the following considerations. From the observations of M. de Quatrefages†, it appears that in some genera, at a

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* The phenomena of fissiparous generation in these Annelidans will be better understood by reference to Mr. Newport's important discoveries relative to the growth of the *Myriapoda*.—Vide *post*, § 732.

† Ann. des Sci. Nat. 1844.

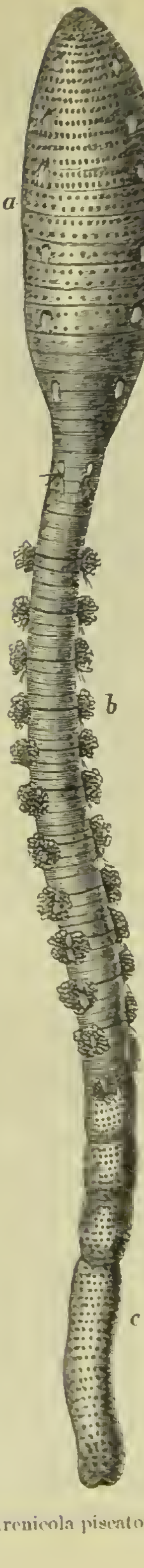
certain period of their growth, a new individual, entirely appointed for sexual reproduction, is developed from the posterior part of the body, from which it separates itself after having remained for some time adherent thereunto. Now these young Annelidans, thus formed by a process of gemmation, are developed precisely in the same position as the new segments of the larvæ, that is to say, between the anal ring and the last zonule of the trunk; but they are not all formed at the same time, and, from the different stages of development at which they had each arrived in the individual described above (§ 661), it was evident that the youngest were placed nearest to the trunk of the parent animal. The first-formed young one, therefore, had been, as usual, primarily situated between the terminal segment of the trunk of the adult Annelid and its anal segment, which, being consequently pushed backwards, had ceased to belong to the parent stock and had become a constituent part of the newly-formed young one; the second must, consequently, have been developed between that first formed and the same terminal joint of the trunk of the parent, and could have had no relation whatever with the original caudal segment, and so on for the third and fourth, &c.,—proving that the penultimate segment of the body, and not the caudal ring, constitutes the point from which development emanates. The gemmiparous production of a new individual resembles, therefore, to a certain extent, the formation of the new zonules in the body of the larva: only, in the latter case, the reproductive ring loses its creative power as soon as it has given birth to a new segment, with which it becomes intimately connected, and which, in its turn, assumes the reproductive faculty; whilst, on the contrary, in the process of multiplying individuals by gemmation, the product becomes, to a certain extent, separated from the economy of the parent animal, and the reproducing segment retains its gemmigerous faculty and gives origin to a series of new beings, one after the other, the last-formed pushing their predecessors further back as they are successively developed.

(664.) Some curious speculations have been entertained by continental writers relative to this mode of propagation. The tail of the original Nereis is still the tail of its offspring; and however often the body may divide, still the same tail remains attached to the hinder portion, so that this part of the animal may be said to enjoy a kind of immunity from death.

(665.) In *Arenicola piscatorum* (fig. 125), a worm met with abundantly upon our own coasts, and eagerly sought after as a bait by fishermen, who dig it from the holes that it excavates in the sand, the branchiæ (*b*) are confined to the central portion of the body, where they form on each side a series of bunches, remarkable during the life of the creature for their beautiful red colour, derived from the crimson blood that circulates copiously through them.

(666.) Respiration is performed in *Arenicola* by means of naked blood-vessels, projecting, in the adult worm (fig. 125, *b*), at the root of the setiferous processes upwards and outwards one-fourth of an inch from the surface of the body. They are limited in number and distribution to the fourteen or sixteen middle annuli or segments. These external branchiæ are commonly described as forming simply arborescent tufts; the division of the vessels is, however, found, on more minute examination, to be regulated in accordance with a fixed principle. When fully injected with blood, the vessels of each branchia form a single flattened plane, which rises obliquely above and across the body immediately behind each brush of setæ. In the adult animal each gill is composed of from twelve to sixteen primary branches arising from a single trunk that proceeds from the great dorsal vessel: the vessels in the branchial tuft describe zigzag outlines,—the secondary branches projecting from the salient point or the outside of each angle of the zigzags, and the tertiary from similar points on the secondary branches. This mode of division, occurring in one place and in all the smaller branches, results in a plexus of vessels of great beauty of pattern or design. Each branchial tuft and each individual vessel possesses an independent power of contraction: in the contracted state the tuft almost disappears, so completely effected is the emptying of the vessels. The contraction or systole in any given tuft occurs at frequent but irregular intervals: this movement does not take place simultaneously in all the branchiæ, but at different periods in different tufts. The vessels have the appearance of being quite naked; and if examined in the living state, each ramuscule seems to consist of only a single trunklet: if this were really the case, it would of course resolve itself into a tube ending in a *cul-de-sac*, and the blood-movement would be a flux and reflux; but by injection it is easy to show that the finest division of the branchial arbuscule contains a double

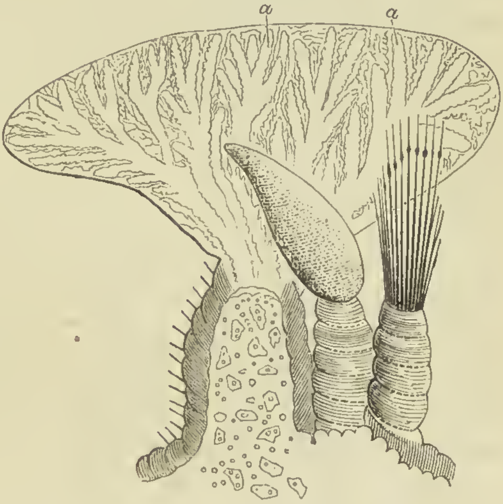
Fig. 125.



Arenicola piscatorum.

vessel enveloped in a common muscular (although extremely diaphanous) sheath. That these vascular sheaths, which are only fine productions of the integuments, are furnished with voluntary muscular fibres, is proved by the rapid and simultaneous retraction of all the branchiæ into the interior of the body which follows when the animal is touched. In *Arenicola*, as in *all* Annelida in which the vessels of these organs are naked, the branchiæ are destitute of vibratile cilia; and it will be found that under such circumstances, namely when the branchial vessels occur as naked projections from the external surface, the description here given of these organs in *Arenicola* will apply in every respect to all other Annelida so furnished. It will be observed that in all the dorsibranchiate genera furnished with branchiæ such as those described above, the true blood, circulating in its proper vessels, is found to be *exclusively* the *seat* and *subject* of the respiratory process; the fluid in the peritoneal cavity, abundant in quantity and highly organized though it be, does not in the least degree participate in this great function. The Dorsibranchiate Annelids may, however, be divided into two great groups, of which one would comprehend those genera in which the function of breathing devolves exclusively on the *true* blood, while the other would be characterized by the fact that the branchiæ are constructed so as to permit more or less completely the exposure, in conjunction with the blood-proper, of the chylaqueous fluid of the visceral cavity to the influence of the surrounding aërating element. Thus it will be seen that when the branchial apparatus is penetrated by two separate and distinct fluids, coordinate probably in organic properties, the vascular system of the body generally will be found so much the less developed, in proportion as the peritoneal fluid supplants the blood in the branchiæ. In those races of Dorsibranchiate worms possessing both these kinds of circulation, naked unciliated blood-vessels no longer form exclusively the branchial organs; loose and large-celled tissue (fig. 126, *a a*) is superadded to the proper blood-vessels, which are far less in relative size than those in the former variety of branchiæ; into the cells of this tissue the fluid of the visceral cavity insinuates itself, its course being marked by a slow motion. There exists, however, another point of structural difference between the

Fig. 126.

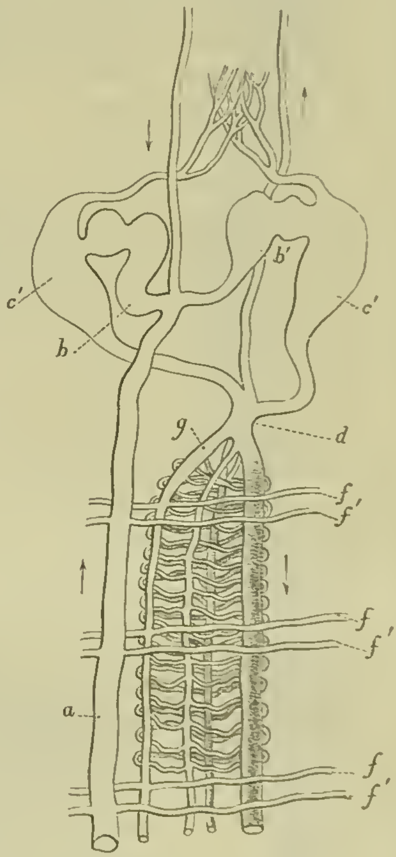


branchial organs of this group and those of the former, viz., that wherever the fluid of the peritoneal cavity is admitted into the interior of the branchial organs, the latter are invariably supplied more or less profusely with vibratile cilia.

(667.) In the branchial structure of worms thus constituted, the branchial appendages are found, instead of being composed of naked vessels, to present the appearance of round or laminated organs, into which the fluid of the visceral cavity freely penetrates.

(668.) The blood-system is more concentrated in *Arenicola* than in any known Annelid. A large dorsal trunk (fig. 127, *a*; fig. 128, *i*), at the anterior three-fourths of the body receiving exclusively the efferent vessels of the branchiæ, proceeds forwards from the tail and empties itself into the cardiac cavities, of which one is situated on either side of the œsophagus (fig. 127, *b b′*; fig. 128, *b b*). Another vessel, proceeding from the head towards the heart, empties itself into the same cavity with the former. The blood then enters a second cavity (fig. 127, *c′ c′*), more ventrally situated, by which it is partly propelled forwards into the subœsophageal trunk, but principally backwards into the great longitudinal trunks of the alimentary canal. The blood returning from the intestinal system of vessels reaches the dorsal intestinal (*g*) (lying in the median line underneath the dorsal trunk), from which the current diverges laterally at right angles into the branchiæ (*f f*). This conformation differs from that prevalent in all other Dorsibranchiate Annelidans, in which the great ventral trunk is the source of the branchial *arteries*. But the typical plan of the circulation is observed in the system of *Arenicola* at the posterior half of the branchial division of the body, where the afferent vessels of the branchiæ emanate from the ventral trunk. It may be necessary to explain that the motion of the blood in that part of the circulating system which is anterior to the heart is the reverse of that posterior to this centre. The

Fig. 127.

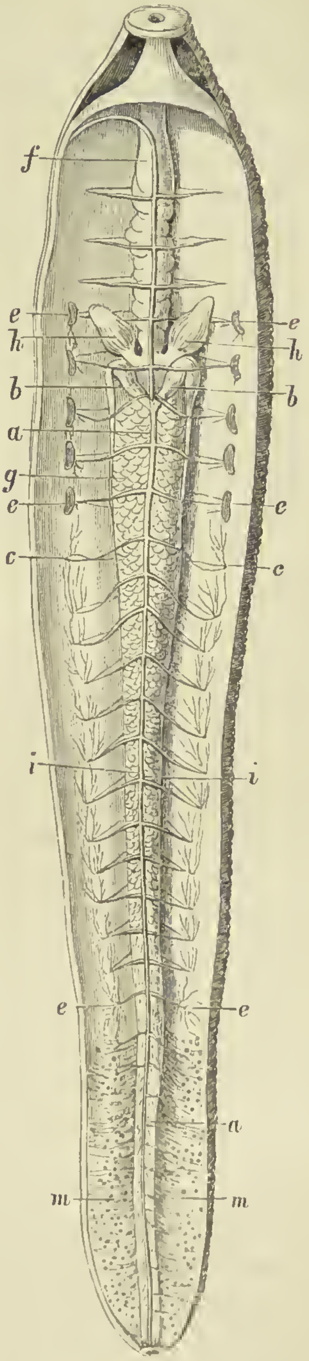


Plan of the circulation in *Arenicola*. (After Dr. Williams.)

ventral œsophageal carries the blood forwards, and the dorsal backwards towards the heart.

(669.) The independent contractile (*ergo* circulating) power of each individual vessel may be very completely proved by an examination of the branchiæ of a living *Arenicola.* A single ramuscule in the branchial tuft may contract and empty itself while the surrounding branches are expanding diastolically. There is no synchronism in the circulatory movements of these vessels. Both the afferent and efferent vessels of the branchiæ are long and tortuous, but discover no cardiac ampullæ in any part of their course. In *Arenicola* the peritoneal chamber is filled with a highly corpusculated fluid, the basis of which consists of sea-water, and the presence and movements of which are indispensable to the circulation of the blood-proper. By this remarkable mass of fluid, the slender tortuous vessels are shielded from injurious pressure.

Fig. 128.



Circulation in *Arenicola*.

(670.) In *Arenicola piscatorum** the generative apparatus consists of six lateral pouches, which during the months of July and August are in a condition of extreme vascularity. They are quite visible to the naked eye by their bright red colour. The minute structure of these pouches can be studied by carefully dissecting them from their attachments to the abdominal wall of the cavity and placing them under the microscope. One of them thus viewed will be seen to consist of a sac or bag, the fundus of which is cæcal. The interior cavity throughout the upper three-fourths is a single undivided space. The attached extremity is formed into two very distinctly marked channels or tubes, the interior of which is formed of cilia that beat in opposite directions. In the glandular tube, the ciliary current sets towards the cavity of the organ; in the

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* Dr. Williams, Phil. Trans. 1858, p. 118.

simple tube it sets out from this cavity. In the fundus the current leads up on one side, and down towards the outgoing limb on the other. The two limbs by which the organ is tied to the walls of the perigastric chamber are not similarly formed. The ingoing limb exhibits a more glandular character, and its walls are considerably thicker and more richly supplied with blood, than the other. About the middle of its course it enlarges into a round gland-like body, the axis of which is perforated by the tube. The ingoing limb commences in an *external* orifice on the abdominal surface of the animal; so that the ingoing current which it serves to convey can only consist of sea-water, which being thus introduced into the cavity, is driven out again, in whole or in great part, by outwardly-acting cilia through the limb, which also opens *externally*: none penetrates into the cavity of the body. Nevertheless Dr. Williams has no doubt, although he has never been able to demonstrate the fact, that the outgoing leg of the looped organ not only communicates directly with the exterior, but also, by a lateral process, opens into the cavity of the body; and by means of this last process, the ova in the female and the sperm-cells in the male reach the perigastric chamber. The ova in the female and the sperm-cells in the male are abundantly found in the fluid of the general cavity; and the ova may also be actually seen in large crowds in the outgoing limb. The ova at this point consist of clear, pellucid germinal vesicles: the vitellus has not yet appeared; after they have sojourned for some time in the general cavity, the latter begins to show itself. According to Dr. Williams, then, the segmental organ is the true ovary in the female and the true testis in the male. The ingoing limb of the organ is a highly glandular structure: its vessels are densely packed and specially arranged; its walls are thick and stromatous; and at its mid-point is a notable glandular development. From the vascular system of this gland proceeds the great vascular organ.

(671.) To the one side of this great vascular system there are appended peculiar cæcal pouches, from the other a dense capillary plexus. This vascular appendage is the morphological equivalent of the blood-system connected with the ovogenetic limb of the segmental organ of the Leech, and of the botryoidal apparatus of vessels connected with the segmental organ of *Lumbricus*, and must either be the receptacle of an extra supply of blood to an organ susceptible of periodical expansion, or it excretes something from the blood-proper into the cavity of the segmental organ which is essential to the further development of the generative products. It is quite certain that the ova and sperm-cells pass through the last stage of their development in the perigastric chamber. How they escape out of this chamber has never yet been proved.

(672.) Rathke and Grube have argued that *Arenicola* is androgynous. De Quatrefages, however, from his knowledge of the development of the spermatic particles, has long recognized the existence of separate sexes*; and long before this, Stannius had concluded that the sexes were separate, from the fact that in different individuals the contents of the general cavity of the body were different†. Stannius also observes that the parent sperm-cells leave the segmental organs (his testes) before the formation of the spermatozoa, which are found only in the cavity of the body. Krohn, Frey, and Leuckart assert that the ova and spermatozoa are developed free in the general cavity of the body.

(673.) In relation to the spontaneous division of the Annelida, Dr. Williams observes:—It is true that, towards the latter end of every summer, certain species of worms are multiplied by a cutting across the body at one or more points. If the fissure occurs at more than one point, the animal, of course, becomes divided into more than two pieces. This circumstance seldom happens. The fissure in *Arenicola* generally occurs somewhere within the middle third of the body, securing a few branchial tufts for each fragment. The tail, however, is sometimes detached, and sometimes the division happens very near the head. This process, in *Arenicola*, happens during July and August. The cephalic and caudal pieces continue for some time to writhe in the sand, somewhat further down in the soil from the surface than the perfect individuals. Towards September, the fragments (both that attached to the head and that belonging to the tail) dissolve away, ring by ring, and finally disappear by decomposition. If the fragment examined be that of the tail, it will be observed at the point of separation to exhibit an eversion of the edges, placing the alimentary canal exteriorly; and a very evident increase of size in the vessels also occurs, accompanied by a tumefied state of all the structures of the part. From this latter fact, it is easy to be misled into the idea that the vessels can become enlarged for no other purpose than that of repairing the injury done by the fissure, or, perchance, of reproducing the part detached by that process. Such would naturally be the meaning which a physiologist would attach to the swollen appearance of the blood-vessels. But such is not the conclusion to which the careful practical observer is conducted by the study of the actual phenomena of the process. It is, of course, indisputable that nature accomplishes some adequate object by the fissure of the body of the worm; but that object, whatever else it be, is unquestionably not that of multiplying the species. The tail-fragment *never*, as can be proved by easy observation, produces a single new ring or segment of the body. If this be true, how completely improbable must be the statement that the headless piece is capable of producing a new head! In *Arenicola*, Dr. Williams can confidently declare that such reproductive properties as those implied in the re-formation, and that too by a remnant of an integral part of the body, do not exist. It is equally inaccurate to maintain that a new tail is formed by the cephalic fragment. This half of the divided worm, like the former, gradually presents evidences of decay: it becomes less and less irritable, the muscles and integuments begin to decompose, the blood-vessels of the branchiæ become black, and the whole disappears by the dissolution of the structures.

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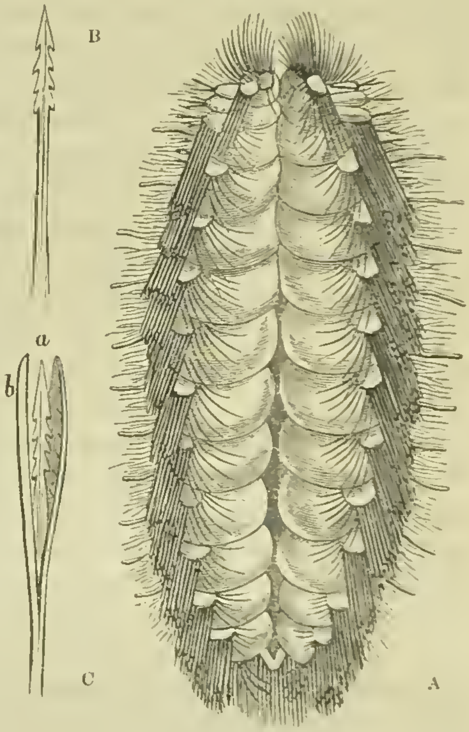
* Comptes Rendus, xvi. 1843.

† Müller's Archiv, 1840.

(674.) The Aphroditaceæ, or Sea-mice, are remarkable for the long hairy tufts with which their pedal appendages are generally furnished (fig. 129). Nothing can exceed the splendour of the colours that ornament some of these fasciculi of hairs; they yield, indeed, in no respect to the most gorgeous tints of tropical birds, or to the brilliant decorations of insects: green, yellow, and orange—blue, purple, and scarlet—all the hues of Iris play upon them with the changing light, and shine with a metallic effulgence only comparable to that which adorns the breast of the humming-bird. But it is not for their dazzling beauty merely that these setæ are remarkable; they are not unfrequently important weapons of defence, and exhibit a complexity of structure far beyond anything to be met with in the hair of higher animals. In the *Aphrodite aculeata*, for example (fig. 129, A), they are perfect harpoons; the point of each being provided with a double series of strong barbs (fig. 129, B); so that when the creature erects its bristles—much more formidable than those of the Porcupine—the most determined enemy would scarcely venture to attack it.

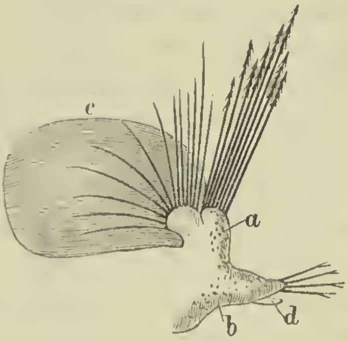
Fig. 129.



Aphrodite aculeata.

(675.) But here we cannot help observing an additional provision, rendered necessary by the construction of these lance-like spines. We have before noticed that the bundles of setæ are all retractile, and can be drawn into the body by the muscular tube from whence they spring. It would be superfluous to point out to the reader the danger which would accrue to the animal itself by the presence of such instruments imbedded in its own flesh, as by every movement of the body they would be inextricably forced into the surrounding tissues. The contrivance to obviate such an accident is as beautiful as it is simple. Every barbed spine is furnished with a smooth horny sheath (fig. 129, c, *a*, *b*), composed of two blades, between which it is lodged; and these, closing upon the barbs when they are drawn inwards, effectually protect the neighbouring soft parts from laceration.

Fig. 130.



Segment of *Aphrodite*.

(676.) In the *Aphrodite* we have an additional appendage developed from the upper part of each lateral oar, in the shape of a broad membranous scale, which, arching inwards over the back (fig. 130, *c*), forms with its fellows a series of imbricated plates, or *elytra*, as they are technically named (fig. 129, A). Each of the elytral scales is formed by a double membrane, between the laminæ of which at certain seasons the eggs are found to be deposited,—a situation evidently adapted to ensure the exposure of the ova to the influence of the surrounding element, and thus to provide for the respiration of the embryo.

(677.) The Aphroditaceæ, indeed, constitute a group of Annelids to which the term 'dorsibranchiate' by no means correctly applies; that is, in the majority of species embraced in this order, no branchial appendages exist, either on the dorsum or any other part of the body. Respiration is performed on a novel principle, of which no illustration occurs in any other family of worms. In all the Aphroditaceæ the blood is colourless. The blood-system is in abeyance, while that of the chylaqueous is exaggerated. Although less charged with organic elements than that of other orders, the fluid of the peritoneal cavity in this famiy is unquestionably the exclusive medium through which oxygen is absorbed. The true Aphrodite type of respiration occurs in *Aphrodite aculeata* (fig. 129, A). In this species, the tale of the real uses of the elytra or scales is plainly told. Supplied with a complex apparatus of muscles, they exhibit periodical movements of elevation and depression. Overspread by a coating of felt, readily permeable to the water, the space beneath the scales during their elevation becomes filled with a large volume of *filtered* water, which during the descent of the scales is forcibly emitted at the posterior end of the body. It is important to remark that the current thus established *laves only* the *exterior* of the dorsal region of the body. It nowhere enters the internal cavities; the latter are everywhere shut out by a membranous partition from that spacious *exterior* enclosure bounded above by the felt and elytra. The complex and labyrinthic appendages of the appendiculated stomach lie floating in this fluid and in the chambers which divide the roots of the feet. From this relation of contact between the peritoneal fluid and the digestive cæca, which are always filled by a dark-green chyle, it is impossible to resist the conclusion that the contained fluid is really a reservoir wherein the oxygen of the external respiratory current becomes accumulated. From the peritoneal fluid the aërating element extends in the direction of the cæca, and imparts to their contents a higher degree of organization. These contents, thus prepared by a sojourn in the cæca of the stomach, become the direct pabulum for replenishing the *true* blood which is distributed in vessels over the parietes of these chylous repositories. The sequence of events now indicated will convey to the mind of the physiologist a clear idea of the mechanism of the processes both of respiration and sanguification, by an arrangement strikingly analogous with what we have already seen in the Asteridæ amongst Echinoderms.

(678.) In order to arrive at a correct knowledge of the reproductive system of this Annelid, specimens of both sexes should be examined in the spring, and again in the autumn. A good example of a female *Aphrodite* being obtained, the dissection should be thus proceeded with :—Pin the animal down to the trough with its back upwards. Open it by a longitudinal incision extending from the tail to the head. The incision should cut through the scales, felt, and integuments, in order to lay open the spacious perigastric chamber. The integuments should now be carefully stretched, and pinned down to the sides, so as to expose the interior. Let the dissection be then gently floated in salt water, and the parts will present the appearance here described. A network of minute tubes or threads will be seen to twine round and embrace the diverticula of the alimentary canal.

(679.) The entire alimentary system must next be taken away, and with it necessarily a considerable portion of the reproductive network. A view will thus be obtained of the attached ends or roots of the branched segmental organs. These roots will be found to equal the alimentary cæca in number, and therefore that of the feet which are situated posteriorly to the proboscidiform œsophagus. They appear under the character of pyriform tubuli, commencing or ending in a single external orifice. Internally they are lined with ciliated epithelium, the cilia being large, dense, and acting with great force and vigour. The current raised by these cilia sets up on one side and down on the other. The ciliated epithelium ceases at the point where the primary branches divide. All the rest of the organ is unciliated, and filled with the reproductive products. This portion is elaborately branched, the branches twining round the diverticula of the stomach. No microscopic object can be more beautiful than a portion of this tubular network. The individual tubes are bridled on one side and glandular on the other.

A similar structure is exhibited by the male tubes*.

(680.) Tubicola.—The two preceding orders of Annelidans are erratic; but in the third we find creatures inhabiting a fixed and permanent residence that encloses and defends them. This is generally an elongated tube, varying in texture in different species. Sometimes it is formed by agglutinating foreign substances, such as grains of sand, small shells, or fragments of various materials, by means of a secretion that exudes from the surface of the body and hardens into a tough membranous substance; such is the case of *Terebella Medusa* (fig. 132). In other cases, as in the *Serpula contortuplicata* (fig. 131), the tube is homogeneous in its texture, formed of calcareous matter resembling the shells of certain bivalve mollusca, and apparently secreted in a similar manner. These tubes are generally found incrusting the surface of stones or other bodies that have been immersed for any length of time at the bottom of the sea; they are closed at one end, and from the opposite extremity the head of the worm is occasionally protruded in search of nourishment. It must be evident that, in animals thus encased, the character of the respiratory apparatus must be considerably modified*; instead, therefore, of the numerous branchiæ appended to

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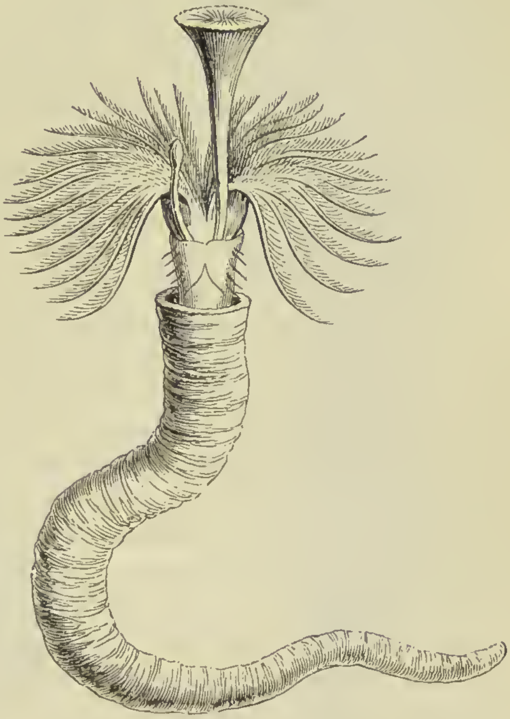
* Dr. Williams, Phil. Trans. 1858, p. 134.

Fig. 131.



Serpula contortuplicata.

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* M. de Quatrefages gives the following *résumé* of the various modifications met with in the respiratory apparatus of the Annelidans :—

"1. Respiration general and entirely cutaneous (*Lumbriconereis*).

"2. Respiration cutaneous, but confined to certain segments (*Chætopterus*).

"3. Respiration cutaneous, but confined to certain points of each segment (*Nereis*).

"4. Respiratory organs taking the form of a simple cæcum or bladder (*Glycera*).

"5. The branchiæ characterized more and more by the formation of a canal in connexion with larger or smaller lacunæ.

"6. These branchiæ may be distributed all along the body (*Eunice sanguinea*).

"7. They may be confined to a certain number of segments placed towards the middle of the body (*Arenicola*, *Hermella*).

"8. They may all be placed at the extremity of the body, so as to form a double tuft."

"The breathing is accomplished," says Dr. Williams, "in every species, the Earthworm not excepted, in strict conformity with the aquatic principle. No known Annelid respires on the atmospheric model. In every Annelid the blood, though variable the segments of the body which we have found in the Dorsibranchiate order, the respiratory tufts are all attached to the anterior extremity of the creature, where they form most elegant arborescent appendages, generally tinted with brilliant colours, and exhibiting, when expanded, a spectacle of great beauty. In some species, as in that represented in fig. 131, there is a remarkable provision made for closing the entrance of the tube when the animal retires within its cavity. On each side of the mouth is a fleshy filament resembling a tentacle; but one of these (sometimes the right and sometimes the left) is found to be considerably prolonged, and expanded into a funnel-shaped operculum that accurately fits the orifice of the shell, and thus forms a kind of door, well adapted to prevent intrusion or annoyance from external enemies.

(681.) The curious habitation of the *Terebella Medusa* is constructed by cementing together minute shells and other small bodies (fig. 132). In neither case is there any muscular connexion between the worm and its abode; so that the creature can be readily drawn out from its residence in order to examine the external appendages belonging to the individual segments of its body. When thus displayed (fig. 133), the modifications conspicuous in the structure of the lateral oars are at once seen to be in relation with their circumscribed movements, and offer a wide contrast to the largely-developed spines, setæ, and tentacular cirri met with in the Dorsibranchiata. In the upper part of the body, rudimentary protractile bunches of hairs are still discernible, but so feebly developed that their use must evidently be restricted to the performance of those motions by which the protrusion of the head is effected; while upon the posterior segments even these are obliterated, the only organs attached to the rings being minute foot-like processes adapted to the same office. The tentacular cirri, which were likewise distributed along the entire length of the Dorsibranchiate order, are here transferred to the head, where they form long and delicate instruments of touch, and, most probably, assist materially in distinguishing and seizing prey. The branchiæ, likewise, are no longer met with upon the segments enclosed within the tegumentary tube, but are placed only in the immediate

in colour, is *non-corpusculated*. The converse is true of the chylaqueous fluid, which in every instance abounds in regularly and determinately organized floating cells."

"In the Annelida the function of respiration is discharged under two remarkably distinct conditions. Under the first, the chylaqueous fluid alone is submitted to this process; under the second, the blood-proper fulfils the office. The mechanical organs subservient to this function under the former are constructed on a plan diametrically different from that of those provided under the latter circumstances. In the Annelid, the true blood and chylaqueous fluid, though coexistent in the same organism, constitute two perfectly distinct and independent fluid-systems. There is between them no direct communication of any sort; they are, physically, very dissimilar fluids. An order of branchial organs must therefore be recognized in which, in equal or unequal proportions, the chylaqueous fluid and the blood-proper, either in the same or in distinct appendages, participate in the process of respiration."—Ann. & Mag. Nat. Hist. 1853, vol. xii. p. 393.

Fig. 132.

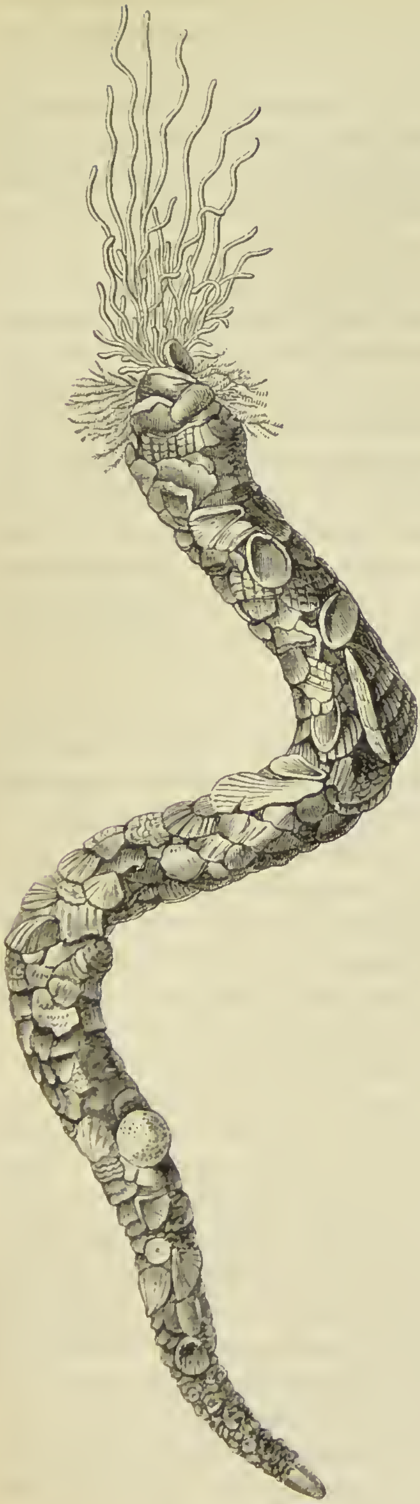
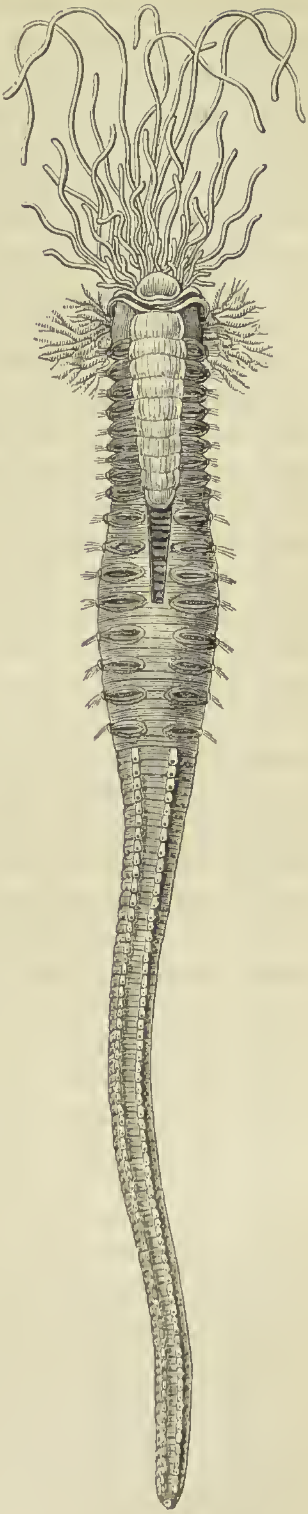


Fig. 133.



Terebella Medusa.

vicinity of the neck, where they form fanlike expansions, or ramified tufts, so arranged as to be most freely exposed to the surrounding medium. The mouth, placed at the origin of the tentacular cirri, is a simple orifice closed with a valve-like flap or upper lip, but is unprovided with any dental structure. The alimentary canal is generally a simple and somewhat capacious tube that traverses the axis of the body; but in some species, as in *Sabella pavonina,* it assumes a spiral course, making close turns upon itself from the mouth to the anal aperture, which is always terminal.

(682.) The branchial organs, in the genus *Terebella**, appear under the form of blood-red tufts, proceeding from three separate root-vessels on either side of the occiput. The vessels divide for the most part dichotomously, forming an arborescent bunch of florid blood-vessels; each ramusculus is enclosed in a delicate cuticular envelope perfectly destitute of cilia, and is, moreover, double—that is, composed of an afferent and efferent vessel. Although extremely transparent and attenuated, the cuticular structure embracing these branchial blood-vessels must include some retractile fibres, since each separate ramusculus may be emptied and rendered bloodless by the compression of the parietes, a provision which frequently exists in many parts of the circulating system of the Annelida.

(683.) The cephalic tentacles of the Terebellæ present a problem interesting alike to the physiologist and the mechanician. From their extreme length and vast number, they expose an extensive aggregate surface to the agency of the surrounding medium. They consist, in *Terebella nebulosa,* of hollow, flattened, tubular filaments, furnished with strong muscular parietes. Each of these hollow baud-like tentacula may be rolled longitudinally into a cylindrical form, so as to enclose a hollow semicircular space if the two edges of the band meet, or a semicylindrical space if they only imperfectly meet. This inimitable mechanism enables each filament to take up and firmly grasp, *at any point of its length,* a molecule of sand, or, if placed in a linear series, *a row* of molecules. But so perfect is the disposition of the muscular fibres at the extreme end of each filament, that it is gifted with the twofold power of acting on the *sucking* and on the muscular principle. When the tentacle is about to seize an object, the extremity is *drawn in,* in consequence of the sudden reflux of fluid in the hollow interior; by this movement a cup-shaped cavity is formed, in which the object is securely held by atmospheric pressure: this power, however, is immediately aided by the contraction of the circular muscular fibres. Such are the marvellous instruments by which these peaceful worms construct their habitations, and probably sweep their vicinity for food.

(684.) The inferior aspect of each of these tentacles is profusely clothed with cilia, and this side is thinner than the dorsal. The peritoneal fluid, which is so richly corpusculated, and which freely enters the hollow axes of all these tentacles, is thus brought into contact with the surrounding water.

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* Dr. Williams, *loc. cit.* p. 194.

(685.) In addition to the two important uses already assigned to the tentacles in the Terebellæ, they constitute also the real agents of locomotion. They are first outstretched by the forcible ejection into them of the peritoneal fluid, a process which is accomplished by the undulatory contraction of the body from behind forwards; they are then fixed like so many slender cables to a distant surface; and then, shortening in their lengths, they haul forwards the helpless carcass of the worm.

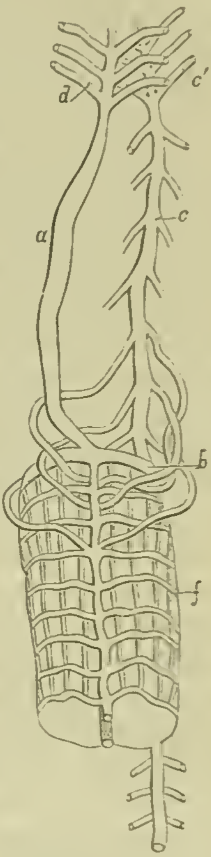
(686.) In the Terebellæ, in consequence of the concentration of the tentacles and branchiæ around the head, the blood-system at this extremity of the body discovers a great increase of development. The peritoneal fluid in this genus is very voluminous and densely corpusculated; the system of the blood-proper is, notwithstanding, elaborate and full-formed. The chamber of the peritoneum is one undivided space,—the segmental partitions of the Earthworm and the Leech being here replaced by limited bands proceeding from the intestine to the integument, tying together these two cylinders—so, however, as to permit one to move within the other with remarkable freedom.

(687.) The great dorsal vessel in *Terebella nebulosa* is limited to the anterior of the body (fig. 134, *a*). It emanates chiefly from a large circular vessel (*b*) embracing the œsophagus, and which receives all the blood from the intestinal system. In this species, therefore, the primary and intestinal dorsal trunks over the whole intestinal region are united, or the former vessel is superseded by the latter.

(688.) On the dorsal view of the œsophagus, a large, pulsatile, fusiform vessel (*a*) is displayed on the first laying open of the integument in a longitudinal direction. Slightly attached to the structure on which it rests, it appears as if suspended in the fluid of the peritoneal cavity. Advancing to the occipital ring, it breaks out into six branches (*d*), of which three proceed to the branchiæ of each side, while the reduced continuation of the original trunk furnishes minute ramuscules to the tentacles, in the hollow axes of each of which an afferent and efferent vessel is contained, surrounded by the peritoneal fluid, which penetrates to the remotest ends of these exquisite organs. Both from the tentacles and branchiæ the blood now returns into the great ventral trunk (*c*), which to the posterior extremity of the body is distinct from, and independent of, the intestinal system (*f*). From this trunk branches are detached on either side of the median line for the supply of the feet and integument.

(689.) At the point corresponding with the circular vessel (fig. 134, *b*), the primary ventral sends off a considerable division for the supply of the intestinal system. The current, therefore, entering the glandular parietes of the intestine is purely arterial in this genus; for it is unmixedly composed of blood returning from the tentacles and branchiæ, by both of which the function of respiration is performed. Here, again, there exist but two principal directions in which the blood circulates, viz. longitudinally and transversely, or circularly, the former currents being connected with the latter. The circular vessel (fig. 134, *b*) acts like an auricle; it receives the blood from the intestinal system and delivers it into the great dorsal (*a*). The alimentary canal is embraced in this genus, as in all Annelids, by a framework of longitudinal and transverse vessels (*f*), in which the blood moves backwards below, and forwards above.

Fig. 134.



Respiratory and circulatory apparatus in *Terebella*. (After Dr. Williams.)

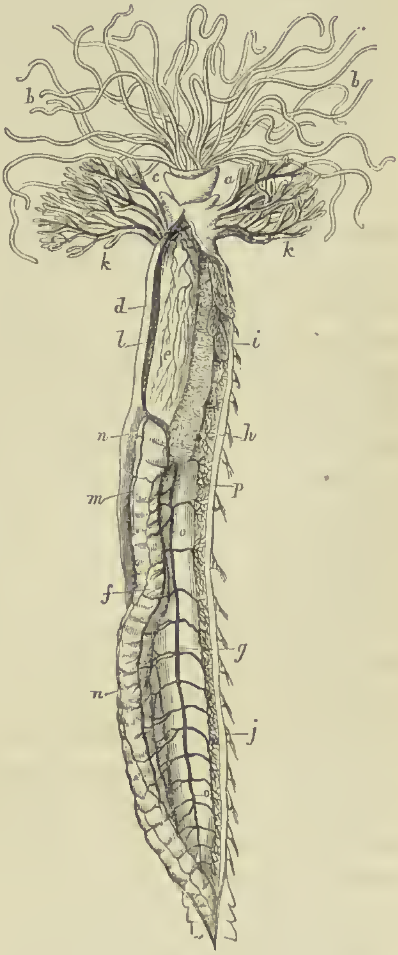
(690.) In the dissection of *Terebella nebulosa*, figured by Milne-Edwards, a large vessel (fig. 135, *l*) is readily distinguishable towards the anterior part of the animal, running along the median line of the back, and situated immediately beneath the integuments. This vessel rests upon the alimentary canal, and exhibits irregular contractile movements whereby the blood contained in its interior is propelled from behind forwards, and consequently performs the functions of a heart; and if we would compare it with what exists in the higher animals, it might be considered as physiologically representing a pulmonic ventricle, seeing that the vessels that convey the blood to the branchiæ for the purposes of respiration take their origin from its anterior extremity.

(691.) By its posterior extremity, the great dorsal trunk receives the blood which it is appointed to propel through the branchial organs, from several large veins which are, for the most part, adherent to the walls of the intestine (fig. 134, *f*), from which they receive a multitude of branches derived from the rich vascular network distributed over the intestinal walls. The principal veins, however, that communicate with this tubular heart are two large transverse trunks which form a ring around the digestive canal, beneath which they unite and become continuous with a large median trunk (fig. 135, *h*) that runs along the under surface of the intestine, from which, in the same manner as the dorsal veins, it receives numerous lateral branches derived from the vascular network already mentioned. Lastly, there is a small median trunk, situated upon the internal surface of the integuments of the back (fig. 135, *m*), into which open the veins derived from the different segments of the body, and which likewise communicates with the dorso-intestinal vessel by numerous anastomosing ramifications.

(692.) The vessels above enumerated may be considered as constituting the general venous system of the body; and the blood which they convey to the dorsal trunk is, by the contractions of that vessel, in great part distributed to the branchiæ through three pairs of branchial arteries derived immediately from the dorsal heart. Still, however, all the blood thus moving from behind forwards is not conveyed to the branchial organs, since a certain portion finds its way through a small median vessel to the labial organs and cephalic tentacula.

(693.) After having passed through the branchial organs, the renovated blood is received by vessels which unite to form a median trunk (fig. 135, *o*) that runs beneath the alimentary tube and immediately above the ventral chain of nervous ganglia. This ventral trunk is continued along the whole length of the body, and gives off opposite to each ring a pair of transverse vessels, which, after having supplied branches to the integument and locomotive organs, bend upwards, to be distributed over the walls of the intestine, where their ramifications contribute to form the vascular network above alluded to.

Fig. 135.



Arrangement of the vascular system in *Terebella*. (After Milne-Edwards.)

(694.) The ventral vessel and its ramifications fulfil, therefore, the functions of an arterial system; and consequently the branchiæ themselves must be regarded as the agents employed in propelling the blood through the systemic circulation. These organs, indeed, may be observed, at intervals, to contract with considerable energy, and thus materially to assist in urging the blood through the arterial ramifications.

(695.) M. de Quatrefages observes* that both in the Erratic and Tubicolous Annelidans the sexes are separate, and states that the generative apparatus, both in the males and females, is restricted to the abdominal portion of the body. According to this distinguished anatomist, the testicle consists of a kind of areolar web of extreme delicacy, which, arising from a median aponeurosis, adheres to the internal and inferior surface of the general cavity, rising as high as the middle of the digestive canal. The tenuity of this tissue is such that it is impossible to procure more than small fragments for microscopic examination.

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* "Mémoire sur les Hermelliens," Ann. des Sci. Nat. 3 sér. 1848.

(696.) The ovary is in every respect similar to the testicle: perhaps its texture may be rather firmer, but not sufficiently so to be adapted for satisfactory histological distinction.

(697.) In the males as well as in the females, but more especially in the latter, during the period of reproduction a pigment is secreted in great abundance, which lines the generative organs; but in proportion as the ova or zoosperms become developed, the amount of this pigment diminishes. Both the ovary and testicle are evidently temporary organs, no traces of them being distinguishable in the generality of specimens; and moreover, in proportion as their products become developed in the general visceral cavity, they become gradually atrophied. When the male secretion is at maturity, a jet of water washes away the spermatozoids, and no trace of the testicle is left; on the contrary, when the sperm is immature, washing still leaves behind a delicate web almost resembling a light cloud.

(698.) The segmental organs in the genus *Terebella*, in all essential particulars, agree in their general structure with those of *Arenicola*. They differ in number in different species: thus, in *Terebella nebulosa* there are sixteen pairs, in *T. conchilega* only six, and in *T. multisetosa* twenty-four. The testes in the male Terebella, according to Dr. Williams, are the lateral pouches or true segmental organs; in the female, these are the ovaria: the generative products in both sexes are early introduced into the general cavity, in the fluid of which they become rapidly developed. There exists, however, in the Terebellæ a large glandular mass extending from the head, along the median line, to some distance in the direction of the tail. This glandular-looking organ coincides internally with the smooth, foot-like, dense tegumentary structure observable on the thoracic half of the abdominal aspect of the body externally, and has been described by Cuvier, Milne-Edwards, De Quatrefages, Grube, Stannius, and others as the testes. It would seem however, from the researches of Dr. Williams, that they have nothing to do with the generative system. They are present alike in the male and in the female. They consist of follicles filled with large fatty particles; and their office seems to be to supply the lubricating and cementing fluid by which the animal forms and moulds its tube.

(699.) In these Erratic Annelidans, according to M. de Quatrefages*, the eggs, as well as the spermatozoids, which exist in a very rudimentary condition in the ovary or the testicle, break loose into the abdominal cavity, where, insulated from all the solid parts, and without any connexion with the vascular system, they undergo all the principal phases of their development. "It appears," says M. de Quatrefages, "that the liquid which thus bathes them on all sides must be vitalized, and that it is from it that they receive the materials necessary to enable them to grow to ten times their original size; in fact, this fluid acts the part of an ovary and of a testis to them. The liquid enclosed in the general cavity of the body of the Annelidans is therefore in some respects a fluid organ."

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* "Sur le Sang des Annélides," Ann. des Sci. Nat. 1846.

(700.) The spermatogenous masses floating in the fluid contained in the general cavity of this Annelid are irregularly ovoid, and present themselves, as is usual, in different stages of development. At first they are perfectly diaphanous, smooth, and manifestly homogeneous, without any trace of an enveloping membrane. The dimensions attained by them in this condition reach to as much as $\frac{1}{16}$th of a millimetre in length, and $\frac{1}{23}$rd of a millimetre in breadth.

(701.) At this epoch they may be seen to exhibit two grooves, crossing each other at a right angle, and whose direction does not appear to present any constant relation with the form of the mass itself. The number of grooves soon increases, and they become more marked and deeper, and the mass, after having presented a surface subdivided into large irregular lobes, assumes a mulberry-like aspect, and ultimately becomes completely granular. During the time that these phenomena are being manifested, the mass continues to increase in volume, and in its ultimate condition it is sometimes $\frac{1}{12}$th of a millimetre long by nearly $\frac{1}{16}$th of a millimetre broad.

(702.) The masses, when a little further advanced, split up, and the tail of the spermatozoids is then apparent. The spermatozoids continue to adhere together for some time longer by their bodies, as well as to the granulations not yet transformed: ultimately they are gradually separated.

(703.) At the moment when the spermatozoids separate themselves from the minute masses of which they constitute a part, their body is almost fusiform, and perhaps not more than $\frac{1}{100}$th of a millim. long and $\frac{1}{300}$th of a millim. thick; but they grow during the time they remain in the fluid that bathes them: the body and the tail elongate, and, besides this, the former increases considerably in its transverse diameter. Among spermatozoids quite mature, some will have attained to a length of $\frac{1}{60}$th of a millim., and a breadth of $\frac{1}{150}$th of a millim.

(704.) According to Dr. Williams*, here, as elsewhere throughout the class of Annelidans, the segmental organs are to be regarded as the primary parts of the reproductive system. Throughout the Nereid group, the ciliated, horseshoe-shaped segmental organ exists. It consists of a tube, highly ciliated, both ends of which communicate with the *exterior*: the ingoing limbs are situated in the immediate vicinity of

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* Phil. Trans. 1858, p. 124.

each dorsal foot; the outgoing limbs, considerably longer and more tubular than the former, open externally to the median side of the root of each ventral foot. The cilia with which this horse-shoe tube is lined are highly vigorous, and capable of supporting a powerful current, which arises externally and terminates externally; but, as Dr. Williams asserts, the ova in the female and the sperm-cells in the male escape, although in some undetermined mode and by some undemonstrated passage, from this organ into the complexly areolated tissue which fills the chamber of the pedal appendages, which is a development of the segmental organ, and in size and vascularity is proportionate to the stage at which the contained germinal elements have arrived.

The following observations of M. Sars*, relative to the embryogenesis of these worms, are extremely interesting and important:—

(705.) In *Polynoë cirrata* the months of February and March are the period of propagation, when the body assumes a pale rose colour, arising from a numberless quantity of eggs, which fill the abdominal cavity, with the exception of about the first anterior fourth, and appear everywhere through the skin. When the animal is opened, the eggs appear to hang together in masses by means of a connecting tenacious mucus. In other individuals the eggs occur on the top of the back of the mother, beneath the dorsal scales, in immense numbers, surrounded by a tenacious mucus. The heaps of eggs cover the whole hinder half of the back, but, more anteriorly, only the sides above the bases of the feet. It would seem that the eggs pass out through a very small aperture just above the feet, as Rathke found in the case of *Nereis pulsatoria*. Here, protected beneath the dorsal plates, the eggs remain until the young escape. In the meantime the yelk undergoes the usual process of mulberry-fission, until it becomes finely granular. The ova become slightly oval; and the fœtus (into which the entire yelk is converted, without any part whatever separating) is smooth, greyish white, and more or less narrowly enclosed in chorion. A peculiar kind of motion was now observable on placing the separated ova under the microscope, the ova turning round and round: this was effected by a very short fringe, which is seen now and then to move slowly and curve in a worm-like form, drawing the egg with it backwards and forwards. The fœtus itself, which gradually acquires a white greyish-green colour, is still without motion in most of the ova: only, in a few a circle of extremely minute projecting and vibrating cilia was perceptible, which surrounds horizontally the centre of the body of the fœtus, at an equal distance from the two poles of the ovum. At last the fœtus arrives at maturity, and the mother now carries on her back many thousands of young ones, which gradually come forth from the mucus surrounding the eggs, leave their mother, and swim freely about in the water, visible to the naked eye as very minute greenish-grey points ($\frac{1}{20}$th of a millimetre in size)

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* Sars, Wiegm. Archiv, 1845, part 1.

endowed with lively motion. They are extremely unlike their parent both in form and structure, being short, oval, cylindrical, and devoid of segmentation, furnished with a circle of long cilia around the centre of the body, but otherwise without external organs. The portion of the body situated anterior to the ciliary circle is somewhat narrower than the hinder one, and bears two eyes: this is the head; and the young one always swims with this extremity in front. Frequently these young animals revolve, during swimming, around their longitudinal axis. Their sight is distinctly developed; for they avoid each other with adroitness, and always swim towards the light. The time from the extrusion of the young to the laying of the eggs may probably amount to a couple of weeks.

(706.) Many interesting particulars relative to the development of various genera belonging to the class under consideration have been ascertained by Milne-Edwards*. In the *Terebellæ* (fig. 136), according to the observations of this distinguished naturalist, the young, on leaving the egg, have no resemblance whatever to the adult animal, insomuch indeed that it would be difficult to guess, *à priori*, the class to which they really belonged. On their first appearance upon the stage of active existence they might be mistaken for the ciliated larvæ of certain Polyps or Medusæ, presenting no traces of the annulose type of structure (fig. 136, 1): in the course of a short time, however, their bodies become elongated, and they begin to assume somewhat of a bilateral or symmetrical form, the body of the young Terebella becoming distinguishable, divided into four zones or rudimentary segments, the posterior of which is still provided with a ciliary apparatus (fig. 136, 2). Shortly after this, a fifth ring (fig. 136, 3, *d*) begins to make its appearance in the space situated between the penultimate and terminal, and rudiments of a mouth and alimentary canal become distinguishable. The growth of the young Annelidan now begins to advance rapidly; and its body is rendered more worm-like as new segments are progressively added to its length, these all successively making their appearance in the space between the last-formed ring and the anal or terminal joint of the body; so that the relative position of the newly developed segments is precisely in accordance with their respective ages, except in the case of the last segment, which is persistently terminal. Meantime the larva ceases to be, as it was at first, completely apodous: simple subulate setæ, supported upon minute fleshy tubercles, begin to show themselves on both sides of the body, the development of these locomotive appendages being accomplished in the same order of sequence as that of the segments, namely from before backwards.

(707.) At this period of their growth the young *Terebellæ* present the appearance of minute subcylindrical worms (fig. 136, 4), and the different viscera in the interior of the body become very clearly defined.

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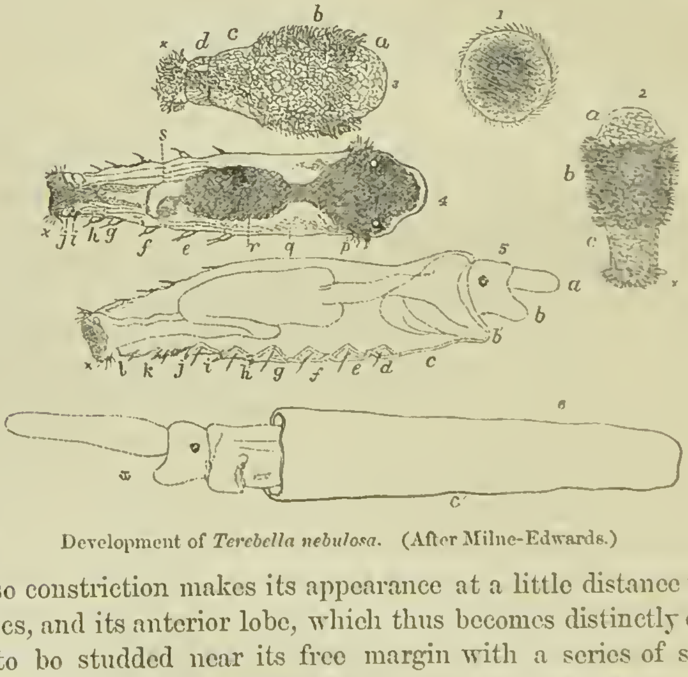
* "Recherches Zoologiques faites pendant un Voyage sur les Côtes de la Sicile, par M. Milne-Edwards," Ann. des Sci. Nat. for 1844.

(708.) The digestive apparatus is now distinctly perceptible: anteriorly it presents a kind of fleshy bulb (fig. 136, 4, *p*); then a short cylindrical œsophagus, followed by a capacious ovoid stomach (*r*), the contents of which appear to be still saturated with the coloured substance of the vitellus, and an intestine (*s*), which commences at about the posterior third of the body. The glandular structures near the anterior part of the animal now become apparent, and the subcutaneous muscles clearly distinguishable; still it is remarkable that, even in the most transparent portions of the creature, no traces of a vascular system can be detected.

(709.) In the course of three or four days more, the cilia have completely disappeared from the surface of the body, which now presents all the characters of one of the erratic Annelids, but in no respect resembles the tubicolous genera to which the creature really belongs. The young larva, in short, is furnished with a distinct head, an antennary organ, eyes, and feet armed with subulate setæ; while the adult Terebellæ are acephalous, being destitute both of antennæ and eyes, and having feet provided with hook-like appendages.

(710.) After the larva has been furnished with one or two additional pairs of feet, the head begins to be changed in its shape (fig. 136, 5), a transverse constriction makes its appearance at a little distance in front of the eyes, and its anterior lobe, which thus becomes distinctly defined, is seen to be studded near its free margin with a series of stinging vesicles, some of which are armed with little spine-like filaments. The post-cephalic ciliated collar becomes at the same time much narrower,

Fig. 136.

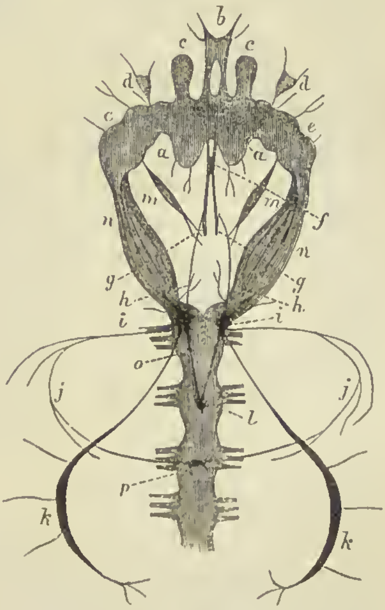


Development of *Terebella nebulosa*. (After Milne-Edwards.)

and forms a prominent ridge underneath the head, that constitutes a kind of upper lip. In the course of two or three days more, the anterior cephalic lobe (136, 5, *a*) becomes perfectly distinct from the oculiferous segment, and is much elongated, taking a cylindrical form, and constituting a very flexible median appendage, having all the characters of an antenniform organ. Its axis is occupied by a canal that communicates with the general cavity of the body; and a fluid may be seen to circulate in its interior. The natatory cilia have almost entirely disappeared both from the neck and from the posterior extremity of the body; and the young *Terebella* in this condition presents itself exhibiting all the characters of an Annelid belonging to the erratic group—not, as yet, at all resembling any of the tubicolous genera, of which it is a member.

(711.) Having become deprived of the locomotive cilia with which they were previously furnished, the larvæ now cease swimming and begin to enclose themselves in a kind of mucous substance, which gradually solidifies, so as to form a cylindrical tube open at both extremities. The first period of their existence, during which they lead an erratic life, then closes, and they begin to assume the habits of their parents. The ventral oars, with their armature of terminal hooklets, are successively developed in a regular series from before backwards, as additional segments are added to the length of the body. The tentacular appendages next begin to be developed from the sides of the head. But it is not before the body has acquired thirty-eight or forty pairs of feet that the branchial apparatus makes its appearance, under the form of two simple tubercles developed from the lateral regions of the neck; these, however, rapidly enlarge, and soon assume the functions which, in the adult animal, they are destined to perform.

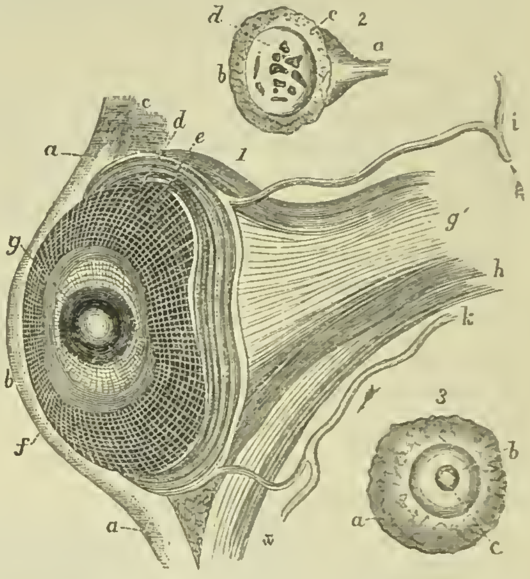
Fig. 137.



Plan of the nervous system in the Dorsibranchiate Annelidans. (After Quatrefages.)

(712.) The structure of the nervous system in the Annelida conforms, in its arrangement, with the general type common to the articulated classes. A considerable supra-œsophageal mass (fig. 137, *a a*) represents the encephalon, in front of which are situated minute ganglia (*b*, *c*, *d*, *e*), from whence nerves are derived to supply the principal instruments of sensation connected with the cephalic portion of the animal. The circum-œsophageal ring (*n n*) is strongly marked, communicating on each side with the ventral series of ganglia (*o*, *p*) that extends throughout the entire length of the body, giving off nerves to supply the different segments. Communicating with the posterior aspect of the encephalic ganglia are several small ganglionic masses (*i*, *k*, *l*, *m*), which are joined together by delicate filaments, and apparently represent the sympathetic system, inasmuch as from them are derived filaments supplying the alimentary canal and the principal viscera.

Fig. 138.



Structure of the eye in *Torrea vitrea*, and of the supposed auditory apparatus in *Arenicola* (after Quatrefages). 1. *a a*, integument passing in front of the eye, and forming a transparent cornea; *b*, *c*, granular cellular tissue enclosing the globe of the eye; *d*, external surface of reticular pigmental membrane; *f*, internal surface of the same, seen through the pupillary aperture; *e*, the iris; *g*, the crystalline lens; *g'*, optic nerve; *h*, sheath of ditto, derived from the dura mater; *i*, *k*, vascular trunks forming a circle around the base of the eyeball. 2. Auditory apparatus of an *Arenicola*: *a*, acoustic nerve; *b*, *c*, cellular tissue investing the auditory capsule; *d*, otolithic masses. 3. Auditory apparatus of *Amphicoryne*: *a*, cellular tissue; *b*, auditory capsule; *c*, otolith.

(713.) In *Torrea vitrea* (an Annelid the transparency of which is such that, when plunged into sea-water, its presence is only distinguishable from the bright red colour of its eyes and a double line of violet-coloured spots that extend along its back), M. de Quatrefages* was enabled to examine the structure of the organs of vision in a very satisfactory manner. The eyes in this species are only two in number; and, indeed, they constitute by far the larger part of the creature's head, forming two very considerable prominences that are almost conjoined in the mesial line of the body. The integument, which is here extremely thin and perfectly diaphanous, passes over the ocular globe, and evidently in this case performs the functions of a transparent cornea (fig. 138, 1, *a*). A thick fibrous stratum, representing the sclerotic (*d*), encloses the eye, and becomes continuous with the sheath, likewise fibrous (*h*), of the optic nerve (*g'*). The colourless sclerotic presents upon one side a large irregularly-rounded aperture that is partly closed by a sort of choroid of a brownish colour (*b*). in the centre of which is an almost circular pupil surrounded with a border of a deep blue colour. Through the pupillary opening it may be perceived that the interior of the eye is lined by the choroid, and that the whole interior of the ocular capsule is filled up with a vitreous humour so absolutely transparent that the crystalline lens situated in its centre seems to be in connexion with nothing. On the outside of the eye the optic nerve can be plainly seen arriving at the eyeball and expanding to form the *retina*. The eyes of other Annelidans are, however, when present, by no means so easily examined; they may, however, from the researches of Müller*, Wagner†, Rathke‡, and Siebold§, be briefly stated to consist of a round transparent medium or lens enclosed in a layer of pigment, and provided posteriorly with a retinal expansion.

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* Ann. des Sci. Nat. 1850.

(714.) An apparatus to which the functions of an organ of hearing have been attributed by several eminent anatomists is met with in some Annelidans. Grube and Stannius || first announced a very remarkable structure in *Arenicola*, the existence of which has been confirmed by subsequent observers, that certainly resembles very closely in its conformation an organ common among the Mollusca, to which a similar function has been generally conceded: this consists of a transparent membranous capsule (fig. 138, 2 & 3, *a*, *b*, *c*) enclosing a fluid, wherein one, or sometimes several minute bodies, having every appearance of otoliths, are suspended. M. de Quatrefages describes these auditory capsules as being situated in the first or second segment of the body, one on each side of the opening of the œsophagus, and observes that a nerve of considerable size is distinctly traceable in them.

(715.) Many of the smaller marine Annelids are luminous; their luminosity, however, is not a steady glow like that of the glow-worm or fire-fly, but a series of vivid scintillations (strongly resembling those produced by an electrical discharge through a tube spotted with tin-foil) that pass along a considerable number of segments, lasting for an instant only, but capable of being repeatedly excited by any irritation applied to the body of the animal. These scintillations may be observed even in separated segments if they be subjected to the irritation of a needle-point or of gentle pressure; and it has been ascertained by M. de Quatrefages that they are given out by the muscular fibres in the act of contraction¶.

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* Ann. des Sci. Nat. t. xxii.

† Icones Physiologicæ, pl. 28.

‡ De Bopyro et Nereide, pl. 2. figs. 4 & 5.

§ Lehrbuch der vergleichenden Anatomie, p. 200.

|| Lehrbuch der vergleichenden Anatomie von Siebold und Stannius, p. 201.

¶ See his Memoirs on the Annelida of La Manche, in Ann. des Sci. Nat. sér. 2. t. xix. and sér. 3. t. xiv.

CHAPTER XI.

MYRIAPODA*.

(716.) The Annelidans examined in the preceding chapter, with the singular exception of the Earthworm, are only adapted to an aquatic life: the soft integument which forms their external skeleton, and the setiform and tentacular organs appended to the numerous segments of their elongated bodies are far too feeble to support them in a less dense and buoyant element; so that when removed from their native waters they are utterly helpless and impotent. Supposing, however, that, as a mere matter of speculation, it was inquired by what means animals of similar form could be rendered capable of assuming a terrestrial existence, so as to seek and obtain prey upon the surface of the earth, and thus represent upon land the Annelidans of the ocean, a little reflection would at once indicate the grosser changes required for the attainment of such an object. To convert the water-breathing organs of the aquatic worms into an apparatus adapted to aërial respiration would be the first requisite. The second would be to give greater density and firmness to the tegumentary skeleton, to allow of more powerful and accurately-applied muscular force by diminishing the number of segments composing the annulose covering, and also, by converting the lateral oars into jointed levers of support sufficiently strong to sustain the weight of the whole body, to provide instruments of locomotion fitted for progression upon the ground. Yet all these changes would be inefficient without corresponding modifications in the character of the nervous system: the lengthened chain of small ganglia found in the aquatic worms would be quite inadequate to wield muscles of strength adapted to such altered circumstances; the small encephalic brain would be incompetent to correspond with more exalted senses; so that, as a necessary consequence of superior organization, the nervous centres must be all increased in their proportionate development to adapt them to higher functions.

(717.) The changes which our supposition infers would be requisite for the conversion of an aquatic Annelidan into a land animal are precisely those which we encounter when we turn our attention from the creatures described in the last chapter to the Myriapoda, upon the consideration of which we are now entering: they form the transition from the red-blooded worms to the class of Insects, and are intermediate between the two in every point of their structure.

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* *μύρια*, ten thousand, *i. e.* many; *ποῦς*, a foot.

(718.) The body of a *Myriapod* consists of a consecutive series of segments of equal dimensions, but, unlike those of the generality of the Annelida, composed of a dense semicalcareous or else of a firm coriaceous substance; and to every segment is appended one or two pairs of articulated legs, generally terminated by simple points.

(719.) The anterior segment or head, besides the organs belonging to the mouth, contains the instruments of sensation, consisting of simple or compound eyes, and of two long and articulated organs called *antennæ*, generally regarded as appropriated to the sense of touch, but which probably are connected with other perceptions less intelligible to us.

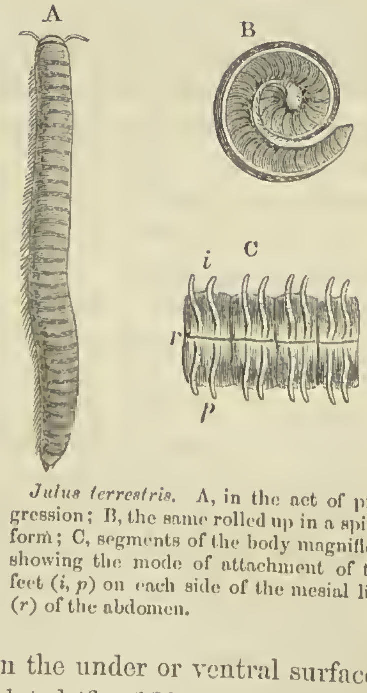
(720.) The air required for respiration is taken into the body through a series of minute pores or spiracles placed on each side along the entire length of the animal, and is distributed by innumerable ramifying tubes or tracheæ to all parts of the system.

(721.) The number of segments, and consequently of feet, increases progressively with age,—a circumstance which remarkably distinguishes the Myriapoda from the entire class of Insects, properly so called.

(722.) The MYRIAPODA may be divided into two families, originally indicated by Linnæus: the *Julidæ*, or millepedes, and the *Scolopendridæ*, or centipedes, each of which will require our notice.

(723.) JULIDÆ.—The lowest division, which derives its name from the *Julus*, or common millepede, is most nearly allied to the Annelidans, both in external form and also in the general arrangement of its different organs; this therefore we shall first examine, and select the *Julus terrestris*, one of the species most frequently met with, as an example of the rest. These animals (fig. 139, A) are generally found concealed under stones, or beneath the bark of decayed timber, where they find subsistence by devouring decomposing animal and vegetable substances. The body is long and cylindrical, composed of between forty and fifty hard and brittle rings, which, with the exception of those forming the head and tail, differ but slightly from each other. Every segment supports two pairs of minute feet, arising close to the mesial line upon the under or ventral surface; but these feet, although distinctly articulated (fig. 139, C, *p*), are as yet extremely small in comparison with the bulk of the animal, and are

Fig. 139.



Julus terrestris. A, in the act of progression; B, the same rolled up in a spiral form; C, segments of the body magnified, showing the mode of attachment of the feet (*i*, *p*) on each side of the mesial line (*r*) of the abdomen.

evidently but mere rudiments of the jointed legs developed in more highly organized forms of homogangliate beings; the movements of the Julus are, consequently, very slow, and the creature seems rather to glide along the ground, supported on its numerous but almost invisible legs, than to walk. When at rest, the body is rolled up in a spiral form (fig. 139, B), the feet being concealed in the concavity of the spire, and thus protected from injury.

(724.) The mouth resembles in structure that of the larvæ of some insects, and is furnished with a pair of stout horny jaws, moving horizontally, and provided at their cutting edges with sharp denticulations, so as to render them effective instruments in dividing the fibres of rotten wood, or the roots and leaves of vegetable substances usually employed as food; and the alimentary canal, which is straight and very capacious, is generally found filled with materials of this description.

(725.) In most points of their internal organization, the Myriapoda resemble insects; and we should only anticipate the observations that will be more conveniently made hereafter did we enter into any minute description of their anatomy: we shall therefore, in this place, simply confine ourselves to the notice of those peculiarities observable in the animals under consideration whereby they are distinguished from insects and entitled to rank as a distinct class. We have seen that, in such of the Annelida as have been most carefully investigated, the orifices of the sexual organs are situated near the anterior part of the body, not, as is invariably the case among insects, at the caudal extremity: in this particular the *Julidæ* still present analogies with the red-blooded worms; for in them the external openings of the male parts are situated immediately behind the base of the seventh pair of legs, and are found to be placed upon minute mammillary protuberances, which are each furnished with a sort of hooked scale, adapted to hold the female during the process of impregnation.

(726.) In the female also, the sexual orifices are advanced very far forward, being situated in the vicinity of the head, between the first and second segments; the sexes, however, as in insects, are perfectly distinct, and the conformation of the internal organs coincides with that type of structure which is common to the insect orders.

(727.) The male generative organs of *Julus* are two elongated and partially convoluted tubes, placed side by side beneath the alimentary canal. The excretory ducts, or terminations of these tubes, run towards the *anterior* part of the body, where they terminate in two minute intromittent organs, situated at the under surface of the seventh segment, immediately behind the seventh pair of legs. As they pass backwards, the secerning tubes, or testes, gradually separate from each other, and have developed from their sides, at short distances from each other, numerous small glandular cæca, which doubtless constitute the secreting portions of the apparatus, or proper testes. The two efferent ducts, whereby the secretion of these cæca is conveyed out of the body, intercommunicate freely by means of short transverse canals, and, from the sacculated appearance that they present towards their termination, appear likewise to perform the office of reservoirs for the seminal fluid.

(728.) In the female *Julus*, the organs of reproduction are as simple in their structure as those of the male. They consist of a single elongated bag or oviduct, covered on its exterior surface with a very great number of ovisacs or cæca of various sizes, each of which secretes but a single ovum. This oviduct extends backwards beneath the alimentary canal from the vaginal outlet, which is double, and situated in the fourth segment of the body, behind the second pair of legs. In the pregnant female the oviduct appears smooth externally, being distended with the ova that have passed into it from the ovisacs where they were formed, and which are retained in readiness to be deposited immediately after intercourse with the male.

(729.) The ova, when fully developed, are found to present all the structures belonging to a perfectly formed egg,—the *yelk*, the *germinal vesicle* with its *macula*, the *membrana vitelli*, the *albumen*, and likewise the *shell*, lined by the *membrana externa*, or *chorion*, being all distinctly recognizable.

(730.) Another important distinction between these animals and insects properly so called, is met with in the mode of their growth and development. Insects (as we shall more fully explain hereafter) undergo a more or less complete change in their outward form as they advance through several preparatory stages to their mature state: during the progress of these changes, that constitute what is usually called the metamorphosis of insects, they are invariably unable to perpetuate their species; and it is only in their last or perfect condition, which is ordinarily of very short duration, that the sexual organs attain their perfect development and are fit for reproduction. In this state all true insects have six legs, which is one of the most important characters of the class. The Myriapoda likewise undergo several changes of form as they advance to maturity; but these changes principally consist in the repeated acquisition of additional legs; so that in their perfect condition, instead of the limited number of six legs met with in insects, these organs have become extremely numerous. The progress of these transitions from their immature to their fully-developed state has been well observed by De Geer* and Savi†; and the result of their observations is here given, in order that the reader may compare the different steps of the process with what we shall afterwards meet with in the more highly organized Articulata.

(731.) The eggs (fig. 140, A), which are very minute, are deposited

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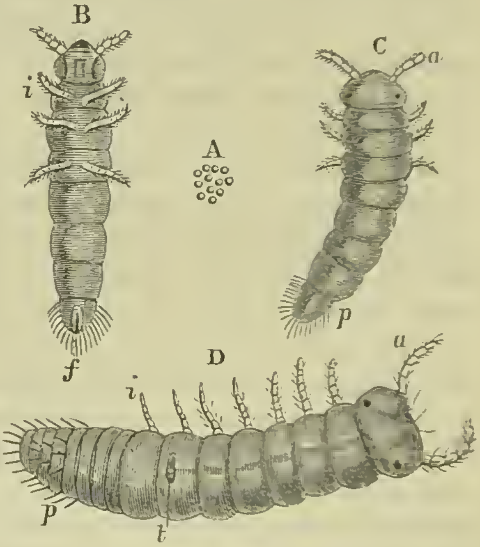
* Mémoires pour servir à l'Histoire des Insectes. 7 vols. 4to. Stockholm, 1778.

† Osservazioni per servire alla storia di una specie di Julus comunissima. Bologna, 1817.

in the earth or vegetable mould in which the *Julus* is usually met with. When first hatched, the young Myriapod is of course exceedingly diminutive; at that period it resembles a microscopic kidney-bean, and is completely destitute of legs or other external organs. After a few days the embryo *Julus* changes its skin, and, throwing off its first investment, appears divided into distinct segments, and furnished with a head, a pair of simple eyes, a pair of antennæ, and six jointed legs attached to the anterior rings of the body (fig. 140, B, C). Some days subsequent to its first moult, the skin is again cast, and the millepede, acquiring larger dimensions, is seen to possess seven pairs of ambulatory extremities, which are, however, still placed only upon the anterior segments (fig. 140, D). When twenty-eight days old, they again throw off their outward covering, and assume, for the first time, their adult form: they then consist of twenty-two rings, and have twenty-six pairs of feet; but, of these, only the eighteen anterior pairs are used in progression. At the fourth moult the number of legs is increased to thirty-six pairs; and at the fifth, at which time the body becomes composed of thirty segments, there are forty-three pairs of locomotive organs. At last, in the adult state, the male has thirty-nine and the female sixty-four rings developed; but it is not until two years after this period that the sexual organs appear and the animals become capable of reproduction.

Fig. 140.

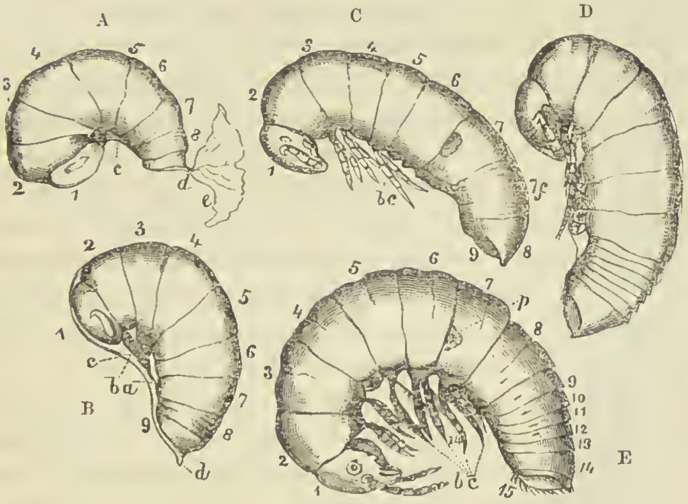


Growth of young *Julus terrestris*. (After De Geer.)

(732.) The development of the young *Julus* has been traced more recently by Mr. Newport with great care; and the result of that gentleman's observations relative to this part of the history of the Myriapods is of extreme interest, both to the physiologist and in an entomological point of view.

(733.) The embryo, when it first becomes distinguishable in the interior of the ovum, is entirely destitute of limbs, or of any appearance of segmental division, and even at the moment of its escape from the egg, which is effected by the laceration of the egg-shell, but very faint traces of segmentation are discernible. After its extrusion, however, its growth advances with considerable rapidity, and it soon becomes visibly divided into eight distinct segments, including the head (fig. 141, A)—the ninth or anal segment (*d*) being still indistinct. The four thoracic segments, moreover, now exhibit on their ventral surface little nipple-shaped protuberances, three of which on each side are the rudiments of future legs. No internal viscera are as yet distinguishable, the whole embryo being still a congeries of vesicles, or cells, in the midst of which some faint traces of a future alimentary canal seem to be indicated. In this state the body of the embryo is completely enclosed in a smooth and perfectly transparent membrane (fig. 141, A, *e*), which seems to contain a clear fluid. This membrane Mr. Newport regards as the analogue of the *amnion*—the *vitelline* or investing membrane of the embryo in the higher animals, and identical with the *membrana vitelli*, or proper membrane of the yelk. It is a shut sac that completely invests the embryo, except at its funnel-shaped termination at the extremity of the body (fig. 141, A, *d*), where it is constricted, and, together with another membrane (which in the unburst egg is external to this and lines the interior of the shell), assists to form the cord or proper funis (*d*) that enters the body of the embryo at the posterior part of the dorsal surface of the future antepenultimate segment, where the mucro or spine exists in the adult animal.

Fig. 141.



Development of the embryo in *Julus terrestris*. (After Newport.)

(734.) A new process is now about to commence—the development of new segments. Up to the present period the posterior part of the body remains less distinctly divided into segments than the anterior, the first five segments being the most distinctly marked; the sixth and seventh now become more defined. It is in the membrane (fig. 141, C, *f*) that connects the seventh with the eighth segment (at the posterior margin of which last the funis (*d*) enters, and which is permanent as the *penultimate* segment throughout the life of the animal) that the formation of new segments is taking place. At this period it is only a little, ill-defined space, that unites the seventh and eighth segments into one mass; but in proportion as the anterior parts of the body become developed, this part is also enlarged, not as a single structure, but as a multiplication or repetition of similar structures.

(735.) About the seventeenth day the little embryo is ready to leave the amnion in which it has been hitherto enveloped. Its body is found to have become considerably elongated, the increase of length being mainly occasioned by the growth of the posterior segments, but more especially by the development of new ones, which now begin to make their appearance in the antepenultimate space (fig. 141, C, *f*), which is, in fact, the proper *germinal space* or *germinal membrane*, whereby the production of all the future segments is effected. The seven anterior segments, including the head, are now greatly enlarged, and the hitherto minute penultimate and anal segments (8, 9) become much enlarged, and rapidly acquire the form they afterwards retain through the life of the animal. This latter fact shows that it is not merely by an elongation and division of the terminal segment that the body of the Julus is developed, but that it arrives at its perfect state by an actual production of entirely new segments, the formation of which is in progress long before they are apparent to the eye, and that the original segments of the ovum into which the animal is first moulded are permanent.

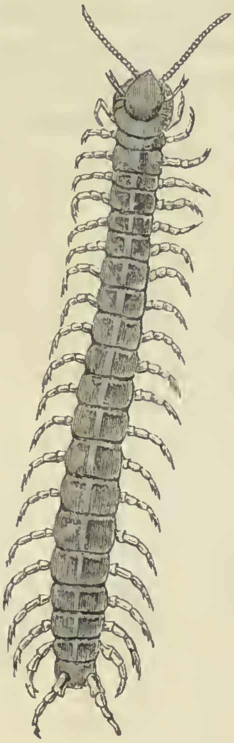
(736.) The manner in which new legs are produced is equally curious. Up to the present period the animal is furnished with only three pairs (fig. 141, C, *b c*), but four additional pairs are nevertheless in progress of formation. These, at present, exist only as eight minute nipple-shaped prominences on the under surface of the sixth and seventh segments (fig. 141, C, 6, 7), four on each, covered by the common integument, which, as in the larval condition of insects, is a deciduous membrane. The newly-formed legs, however, go on rapidly increasing in size until about the twenty-sixth day, when, throwing off the skin in which it has hitherto been encased, the young *Julus* presents itself with seven pairs of legs and a body consisting of fifteen segments (fig. 141, E).

(737). In this condition the body of the animal still continues to elongate, not by the division of the already-formed segments into others, but always by the formation of new ones in the germinal membrane that extends from the posterior margin of the antepenultimate segment to the penultimate, which last segment, as well as the anal, undergoes no change; and it may likewise be observed that that segment of the newly-formed portion of the body is always furthest advanced in growth which is immediately posterior to the last segment which possesses legs,—and then, the next in succession, until we arrive at the terminal ones (the penultimate and the anal), that never have legs appended to them.

(738.) On again casting its skin, the new segments of the body produced at the former change, from the eighth to the twelfth inclusive (fig. 141, E, 8-12), are become of the same size as the original ones, and each has developed from it two additional pairs of legs, so that the whole number becomes increased to thirty-four; and thus at each change of skin the number of new segments and of additional legs is increased, by development from the germinal membrane, until the full complement is acquired.

(739.) Scolopendridæ.—In the second family of Myriapoda we have a very striking illustration of the manner in which the development of the nervous centres proceeds step by step with that of the external limbs. The slow-moving Julidæ possess, in their rudimentary feet, organs adapted to their condition; and their feeble powers of locomotion are in relation with their vegetable diet and retiring habits. But in the predaceous and carnivorous *Scolopendra* (fig. 142), which, although it lurks in the same hiding-places as the *Julus*, obtains its food by pursuing and devouring insects, far greater activity is indispensable; and accordingly we find the segments of the body, and the extremities appended to them, exhibiting a perfection of structure adapted to greater vivacity and more energetic movements.

Fig. 142.



Scolopendra.

(740.) This is at once evident upon a mere inspection of their outward form: the individual segments composing the animal are much increased in their proportionate dimensions, and, instead of being cylindrical, each division of the body is flattened and presents a quadrangular outline. In order to give greater flexibility to the animal, instead of the semicrustaceous hard substance which forms the rings of the Julus, the integument is here composed of a tough and horny substance, forming two firm plates, one covering the back, the other the ventral aspect of the segment, while all the lateral part is only incased in a flexible coriaceous membrane, with which the individual rings are likewise joined together. Such an external skeleton is obviously calculated to give the greatest possible freedom of motion, and thus to enable the *Scolopendra* to wind its way with serpent-like pliancy through the tortuous passages wherein it seeks its prey.

(741.) The ventral chain of ganglia belonging to the nervous system presents a series of nervous centres of dimensions proportioned to the increased bulk of the segments in which they are lodged, and becomes thus fitted to direct the movements of more perfect limbs. The legs, therefore, as a necessary consequence, are now proportionately powerful, divided into distinct joints, and provided with muscles calculated to bestow on them that activity essential to the pursuit and capture of active prey. Thus, then, by a simple concentration of the nervous masses composing the abdominal chain of ganglia, we have the slow-moving and worm-like *Julus* (which we have seen to be, in consequence of its feebleness, restricted to live upon roots and dead substances) converted into the carnivorous and powerful *Scolopendra,* well able to wage successful war with the strongest of the insect tribes, and not unfrequently formidable, from its size, even to man himself.

(742.) The mouth of the *Scolopendra* is a terrible instrument of destruction, being provided not only with horny jaws resembling those of insects, hereafter to be described, but armed with a tremendous pair of massive and curved fangs ending in sharp points, and perforated near their termination by a minute aperture, through which a poisonous fluid is most probably instilled into the wound inflicted by them. It is to this structure that the serious consequences which in hot climates not unfrequently result from the bite of one of these animals must no doubt be attributed.

(743.) In their internal anatomy the *Scolopendridæ* resemble insects even more nearly than the *Julus.* The alimentary canal is straight and intestiniform, but of much smaller diameter than that of the vegetable-eating Myriapoda. It presents an œsophagus and a small muscular gizzard; but there is no perceptible division into stomach and intestine. The respiratory and circulating systems, so far as they are understood, seem to correspond with what we shall afterwards find to exist in the larvæ of insects.

(744.) In the *Scolopendridæ,* as we learn from the researches of Mr. Newport*, the heart is enclosed in a distinct membranous covering, which may be regarded as a true pericardium, consisting of a loose delicate membrane, between which and the sides of each chamber of the heart there is a slight interspace. The heart itself is a long pulsating organ, corresponding in its general structure and position with the dorsal vessel of insects; it is situated immediately beneath the integuments, and runs along the mesial line of the dorsal region of the body, consisting of a series of chambers, twenty-one in number, that communicate with each other and extend through the entire length of the animal from the tail to the cephalic segment.

(745.) The minute structure of the heart is exceedingly interesting. This organ is composed of two distinct contractile tunics, one external and the other internal, each being covered by its proper serous membrane. The external tunic is a very thick muscular layer, the fibres of which are loosely interwoven with each other. The internal tunic is composed of two sets of muscular fibres, of which the inner stratum is disposed longitudinally, while the external one is formed of numerous short, broad, transverse muscular bands, very much resembling in appearance the cartilaginous rings of the trachea in vertebrated animals. They do not completely encircle the longitudinal ones, but pass only halfway round on each side, leaving a space between those of the two sides, both upon the upper and under surface.

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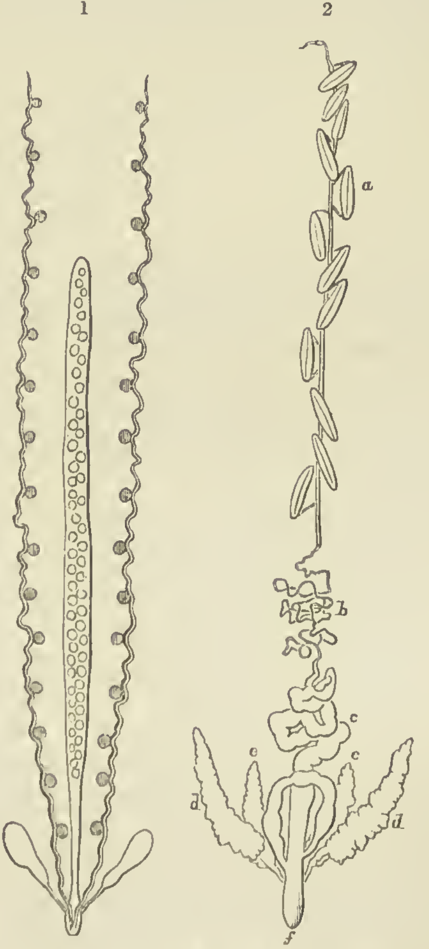
* Phil. Trans. 1843.

(746.) From each compartment of the heart proceed the systemic arteries, which supply nearly the whole of the blood to the viscera and lateral portions of each segment. The anterior pair of these systemic arteries, however, instead of being distributed like the rest, form a vascular collar, which, after surrounding the œsophageal tube (to which, and to the different parts belonging to the cephalic segment, it gives off numerous branches), unites beneath the œsophagus to form the great supra-ganglionic vessel or aortic trunk, extending backwards along the middle line of the body, immediately above the centres of the nervous system (which it supplies plentifully with blood), as far as the terminal ganglion in the last segment, giving off in its course numerous arterial canals, which ramify extensively in the surrounding structures. The return of the blood from the various viscera to the dorsal vessel is effected, as in insects, by lacunar or interstitial channels, as will be explained in the next chapter.

Fig. 143.



1. Female, and 2. Male generative system of *Scolopendra.*

(747.) In the position and arrangement of the sexual organs, the Scolopendridæ complete the transition between the Annelidans and Insects properly so called; for while in *Julus* we have found them still occupying the anterior part of the body as in the former class, in *Scolopendra* they are removed to the tail. The structure of the male organs (fig. 143, 2) is remarkable. The testes are seven in number; and on opening the posterior segments of the animal, they are found closely packed in parallel lines: each testis is composed of two fusiform parts precisely similar to each other; and from both ends of every one of these, which are hollow, arises a narrow duct; so that there are fourteen pairs of ducts arising from the fourteen secreting organs. The ducts all end in a common canal, which gradually becomes enlarged and tortuous, and terminates by a distinct aperture in the vicinity of the anus. Just prior to its termination, the common ejaculatory duct communicates with five accessory glands (fig. 143, 2, *e*, *d d*, *e e*), four of which are intimately united until unravelled, while the fifth is a simple cæcum of considerable length*.

(748.) The ovarian system of the female Scolopendra is a single tube (fig. 143, 1), without secondary ramifications, but receiving near its termination the ducts of accessory glands, as represented in the figure.

(749.) Some Scolopendræ (*S. phosphorea*) emit, in the dark, a strong phosphorescent light; and one species (*S. electrica*) is able to give a powerful electrical shock to the hand of the person who inadvertently seizes it.

CHAPTER XII.

INSECTA.

(750.) The word Insect has at different times been made use of in a very vague and indeterminate manner, and applied indiscriminately to various articulated animals†. In the restricted sense in which we now use it, we include under this title only such of the HOMOGANGLIATA as in their perfect or mature state are recognizable by the following characters, by which they are distinguished from all other creatures.

(751.) The body, owing to the coalescence of several of the segments which compose their external skeleton, is divided into three principal portions—the *Head*, the *Thorax*, and the *Abdomen*. The *Head* contains the oral apparatus and the instruments of the senses, including the antennæ or *feelers*, which are articulated organs presenting great variety of shape, but invariably only *two* in number. The *Thorax*, formed by the union of three segments of the skeleton, supports *six* articulated legs, and sometimes four or two wings; these last, however, are frequently wanting. The *Abdomen* is destitute of legs, and contains the viscera connected with nutrition and reproduction.

(752.) But insects, before arriving at that perfect condition in which they exhibit the above-mentioned characters, undergo a series of changes.

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* *Vide* Cyclop. of Anat. and Phys., art. "GENERATION, ORGANS OF" (Comp. Anat.).

† The word Insect, derived from the Latin word *Insecta*, simply means divided into segments.

both in their outward form and internal structure, which constitute what is generally termed their *metamorphosis.* When this is complete, as for example in the Butterfly, the insect, after leaving the egg, passes through two distinct states of existence before it arrives at maturity and assumes its perfect form. The female butterfly lays eggs which, when hatched, produce, not butterflies, but caterpillars—animals with elongated worm-like bodies divided into numerous segments, and covered with a soft coriaceous integument (fig. 148, A). The head of the caterpillar is provided with horny jaws and several minute eyes: the legs are very short, —six of them, which are attached to the anterior rings, being horny and pointed, while the rest, of variable number, appended to the posterior part of the body, are soft and membranous. The caterpillars, or *larvæ**, live for some time in this condition, and frequently change their skin as they increase in size, until at length, the last skin of the larva being thrown off, the animal presents itself in quite a different form, enveloped in an oblong case, without any external limbs, and almost incapable of the slightest motion—resembling rather a dead substance than a living creature; it is then called a *chrysalis, nymph,* or *pupa*† (fig. 148, B).

(753.) On examining attentively the external surface of this pupa, we may discern, in relief, indications of the parts of the Butterfly concealed beneath it, but in a rudimentary condition. After some time the skin of the pupa bursts, and the *imago*, or perfect insect, issues forth, moist and soft, with its wings wet and crumpled; but in a few minutes the body dries, the wings expand and become stiff, and, from being a crawler upon the ground, the creature is converted into a gay and active denizen of the air (fig. 148, e).

(754.) Such is the progress of the metamorphosis when complete; but all insects do not exhibit the same phenomena. Those genera which, in their mature condition, have no wings, escape from the egg under nearly the same form as they will keep through life; these form the *Insecta Ametabola*‡ of authors: and even among those tribes which, when perfect, possess instruments of flight, the larva frequently differs from the complete insect only from its wanting wings, and the pupa is recognizable by being possessed of these organs in an undeveloped or rudimentary state: an example of this is seen in the House-cricket (fig. 145), in which A represents the imago; B, the pupa; C, the full-grown larva; D, the young just hatched; and E, the eggs.

(755.) The extensive class of INSECTS has been variously arranged by different entomologists, and distributed into numerous orders §. Among the different systems which have been given, we select the following as best calculated to render the reader acquainted with the transformations, as well as the principal forms, to which allusion will be made in subsequent pages.

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* So called, by Linnæus, because in this condition the perfect form of the insect is concealed as it were under a mask. *Larva*, Lat., a mask.

† The first two of these names are purely fanciful: the last is derived from *pupa*, a baby wrapped up in swaddling bands.

‡ *ά*, without; *μεταβολή*, change.

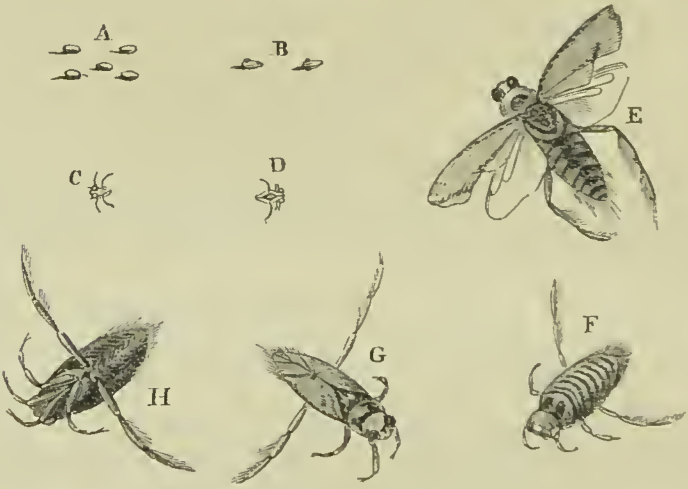
§ The classification of Insects here given is that of Burmeister, which we select

(756.) I. Insecta Ametabola.—The larva resembles the perfect insect, but is without wings. The pupæ of such species as have wings in their imago state possess rudiments of those organs. The pupa runs about and eats.

α. With sucking mouths composed of four fine setæ lying in a sheath.

(757.) 1st Order. *Hemiptera* *.—In such insects of this order as possess wings, which when present are always four in number, the anterior or upper pair are generally coriaceous in their texture for one-half of their extent, while the posterior portion is thin and membranous, —a circumstance from which the name of the order is derived. The *Notonecta*, or Water-boatman (fig. 144), is a familiar example: c and d represent immature, and f mature, larvæ. The pupa (g, h) differs little in outward form from the perfect insect (e), but possesses only the rudiments of wings.

Fig. 144.



Notonecta.

β. Having mouths furnished with jaws, or distinct mandibles and maxillæ.

(758.) 2nd Order. *Orthoptera* †.—In this order the perfect insect possesses four wings, the posterior pair being the largest; and when at

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without giving any opinion as to its relative merits compared with others adopted by different entomologists, but simply as being most convenient for our present purpose. (Manual of Entomology, translated from the German of Dr. Hermann Burmeister by W. E. Shuckard. 8vo. 1836.)

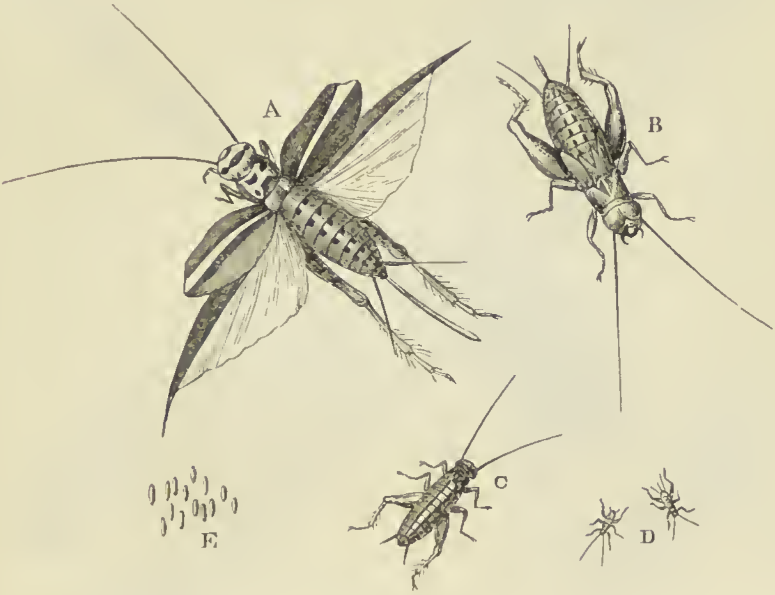
* ἥμισυς, half; πτερὸν, a wing.

† ὀρθὸς, straight; πτερόν.

rest, these are folded both in a transverse and longitudinal direction. The anterior wings are of a denser texture, resembling leather or parchment. To this order belongs the common House-cricket (*Gryllus domesticus*), of which, as well as of its eggs, larvæ, and pupa, figures are here given (fig. 145).

(759.) 3rd Order. *Dictyotoptera**.—This order comprises the Cockroaches, in which the wings are four in number when they exist; but they are generally of equal size, and never folded.

Fig. 145.



Gryllus domesticus.

(760.) II. Insecta Metabola.—The larva is a worm either with or without legs. The pupa is quiescent; or if it moves, it does not eat.

(761.) 4th Order. *Neuroptera*†.—Insects having four equally large or equally long wings with reticulated nervures, and mouths provided with strong lateral jaws. The most perfect examples of this order are the Dragon-flies (*Libellula*), the largest of the insect inhabitants of our own country. The perfect insect (fig. 146), equally remarkable for its beautiful form, powerful flight, and carnivorous habits, is among the most formidable tyrants of its class; while the larvæ, which abound in our ditches and stagnant pools, are eminently destructive to their aquatic companions. The larva (fig. 147, B) possesses six articulated legs; while the pupa (A), which certainly forms an exception to the general rule given above, is not only furnished with rudimentary wings, but is eminently rapacious, and possesses in the structure of its mouth, to be described hereafter, peculiar facilities for gratifying its bloodthirsty disposition.

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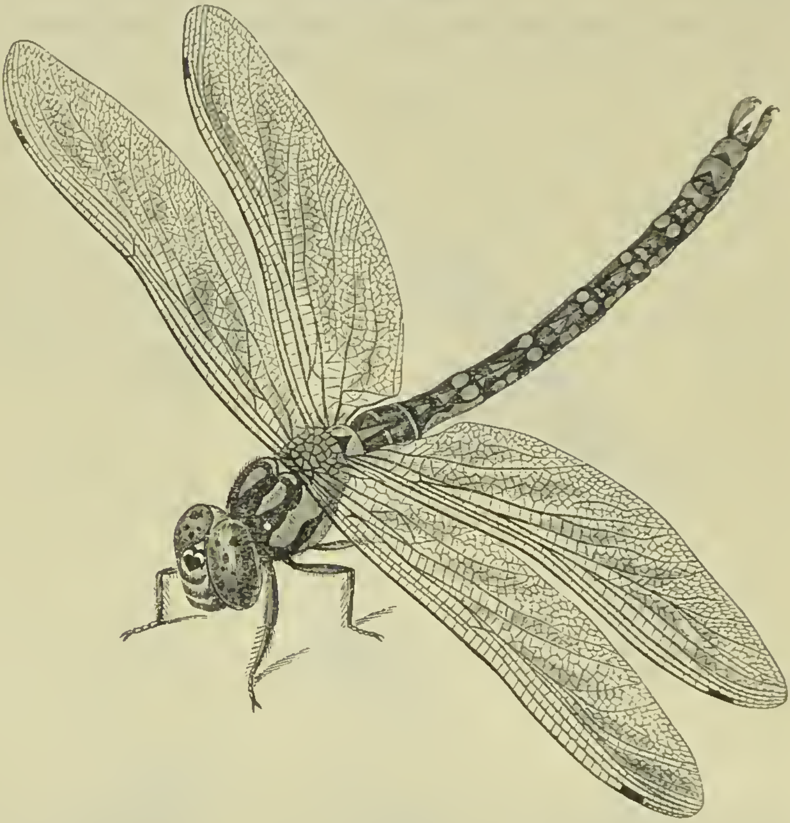
* *δικτυωτὸς*, reticulated; *πτερὸν*, a wing.

† *νεῦρον*, a nerve; *πτερόν*.

(762.) In other orders, the wings are always unequal,—the posterior, and sometimes both pairs, not unfrequently being wanting.

Fig. 146.



Dragon-fly

α. Mouth adapted to sucking.

(763.) 5th Order. *Diptera**.—Instead of posterior wings, we find in this order pedunculated appendages called *halteres* or poisers. The mouth contains a soft proboscis, and is usually armed with several setæ and provided with a pair of palpi: of such the common House-fly affords a familiar instance.

(764.) 6th Order. *Lepidoptera*†.—The insects belonging to the Lepidopterous order are possessed of four wings, which are generally covered with microscopic scales, frequently exhibiting the most beautiful colours. The larvæ are provided with feet and a distinct head; the mouth of the perfect insect is a long spiral proboscis.

(765.) The Butterflies, so conspicuous for their beauty, are well-known representatives of this order; and the usual forms of these insects in the larva, pupa, and imago state are familiar to all (fig. 148, A, B, C).

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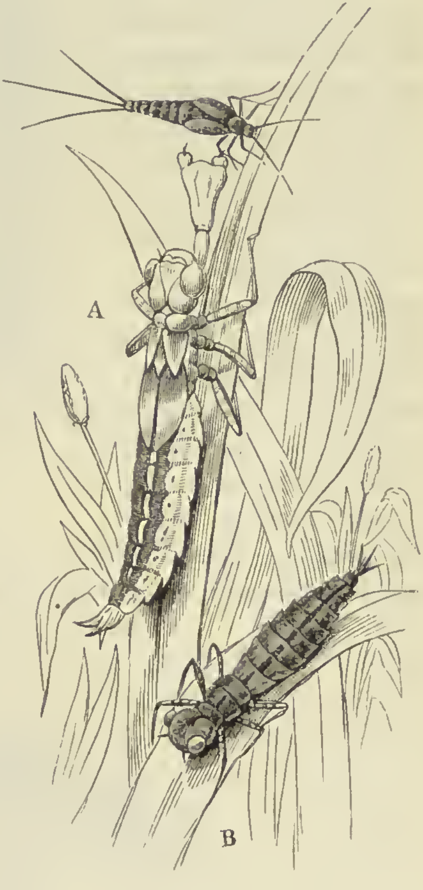
* δίπτερος (δὶς, πτερὸν), with two wings. † λεπὶς, a scale; πτερόν.

β. Mouths with distinct biting jaws.

(766.) 7th Order. *Hymenoptera**.—Possessing four naked wings traversed by ramose nervures. Larvæ generally without head or feet, but sometimes with both. Wasps, Bees, &c.

Fig. 147.



Metamorphoses of Dragon-fly.

(767.) 8th Order. *Coleoptera.*—In this last order, the anterior wings are converted into dense horny cases or *elytra*, beneath which the posterior pair, adapted to flight, are folded up when the insect is at rest. The larvæ possess a head, and are sometimes provided with feet, but not always.

(768.) The Coleopterous division of the insect world embraces the extensive tribe of Beetles, both terricolous and aquatic; of the former we have an example in the common Cockchafer (*Melolontha*), of which a figure is here given, as well as of the different stages of its development (fig. 149, A, B, C, D, E)†.

(769.) Having thus introduced the reader to the chief orders composing the vast class of Insects, our next object must be to examine more in detail the principles upon which these animals are constructed, both as regards their external organization and the nature and arrangement of their internal parts. We shall speak of them in the first place only in their perfect condition, leaving all observations relative to the metamorphoses to which they are subject for subsequent consideration.

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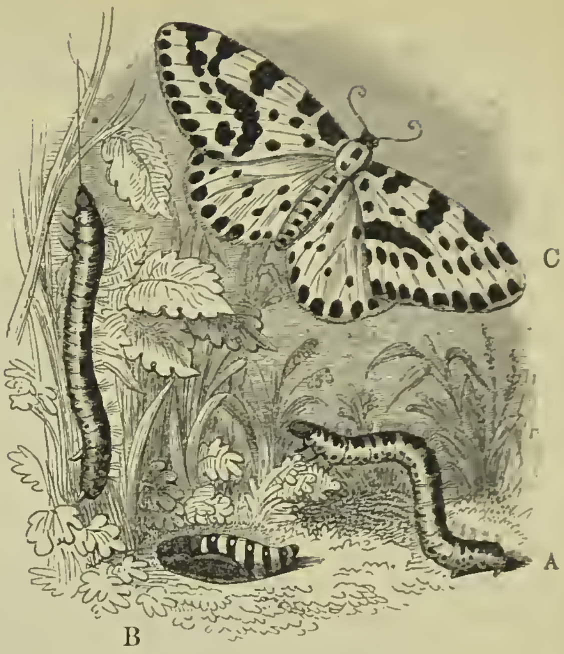
* *ὑμὴν-ένος*, a membrane; *πτερὸν*, a wing.

† It would be foreign to our present purpose to do more than enumerate other Orders of Insects which have been formed by different authors. Of these, the following are the most important:—

Dermaptera (Leach), *δέρμα*, skin; *πτερόν*. *Earwigs* (Forficula).
Trichoptera (Leach), *θρὶξ*, *τριχὸς*, hair; *πτερόν*. *May-flies* (Phryganea).
Aphaniptera (Kirby), *ἀφανὴς*, invisible; *πτερόν*. *Fleas* (Pulex).
Aptera, *ἄπτερος*, without wings. *Wingless insects.*
Parasita (Latreille). *Lice* (Pediculus).
Thysanoura (Latreille), *θυσάν-ουρος*, bushy-tailed. *Spring-tails* (Lepismenæ).

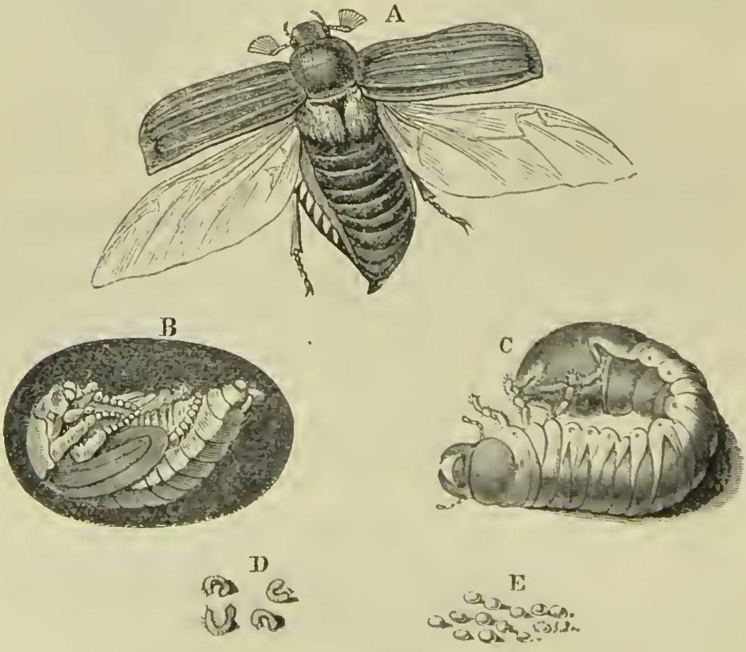
(770.) Insects, examined generally, differ from all other articulated beings in one remarkable circumstance: they are capable of flight, and can maintain themselves in the air by means of wings. It is true, indeed, that some species are met with, in all the orders described above, which are apterous, being destitute of such organs; but these form exceptions, to be noticed hereafter. Such a mode of progression, through so rare a medium as that of the atmosphere, necessarily demands an exercise of muscular power of the most

Fig. 148.



Metamorphoses of Lepidoptera.

Fig. 149.



Metamorphoses of *Melolontha.*

vigorous and active description, and a correspondent strength and firmness in the skeleton upon which the muscles act. It is sufficient to cast a glance at the external construction of any of the Annelidans or Myriapoda which have come under our notice, to be convinced that in such animals flight would be impossible under any circumstances. Their long and flexible bodies present no point to which efficient wings could be appended; neither is any part of their divided skeleton possessed of sufficient strength to support the action of muscles so forcible and energetic as would be indispensable to wield the instruments used in flying, or raise the body above the surface of the ground.

(771.) Similar changes, therefore, to those which we found requisite in order to convert the aquatic Annelid into the terrestrial Myriapod, must be still further carried out before the animals last mentioned could be adapted to become inhabitants of the air. The number of segments composing their elongated bodies must be materially reduced; certain parts of the skeleton must be strengthened in order to sustain the efforts of muscles sufficiently strong to raise the weight of the animal; and, in the last place, the nervous ganglia, by a like concentration of hitherto separated parts, must be gathered into masses of increased power, sufficient to animate the more vigorous muscles with which they are in relation.

(772.) Such changes are precisely those which are most remarkable when we compare the external appearance of a centipede with that of a winged insect: the entire number of segments, and consequently the proportionate length, of the latter is obviously reduced. The head is seen to be more distinct from the rest of the body, to which it is connected by a moveable joint. The three anterior segments of the trunk become largely developed, and, from the density of their substance, form by far the strongest part of the skeleton, constituting what is called the *thorax* of the insect; they are, moreover, generally united together, especially the two posterior, so as to be consolidated, as it were, into one piece; and to these rings only, the organs of locomotion are appended. The remaining segments of the body are much less firm in their texture, especially in insects with hard or horny wing-covers, in which indeed they are almost of a membranous consistence, so as to increase, as far as possible, the lightness of the animal in parts where strength is not required. Here, then, is an annulose skeleton adapted to flight; dense and unyielding where support is required for the attachment of the locomotive organs, but thin and flexible elsewhere.

(773.) The above conditions being required in the arrangement of the pieces which compose the outward framework of the body in insects, we may easily conceive that the mode of union between the various segments above described is by no means a matter of indifference, inasmuch as very different degrees of motion are required between the individual rings. In the Annelida and Myriapoda a very simple kind of junction was sufficient; for in them the segments were all united by the mere interposition of a thinner coriaceous membrane extending between their contiguous margins; but in insects several kinds of articulation are met with in the construction of the trunk, adapted to the mobility of different regions.

(774.) The first mode of connexion is effected by *suture*, or rather by a species of "*harmony*," as it is technically termed by anatomists; two plates of the skeleton being accurately and immoveably fitted to each other, but without being decidedly fastened together by serrated edges. This kind of junction is met with in the thorax, and serves an important purpose; for at the point of union both plates are bent inwards, and prolonged internally, so as to form numerous partitions and processes, from which the muscles moving the wings and legs derive extensive origins.

(775.) A second means whereby the pieces of the thorax are fastened together is by *symphysis*, in which a somewhat soft membrane is interposed between two plates, so as to admit of a slight degree of motion.

(776.) More extensive movement is required between the pieces which compose the abdomen; for in this region, that rigidity and firmness which are essential in the construction of the thorax would be highly disadvantageous, inasmuch as the abdominal viscera must be subject to constant variations in bulk, caused either by food taken into the intestines, or, in the case of the female, by the development of the eggs after impregnation. The rings of the abdomen are therefore united by a membrane passing from one to another,—but so loosely, that the edges of the individual plates wrap over each other to some extent, and thus may be separated by the slightest pressure from within.

(777.) But in other regions there is an absolute necessity for a mode of communication intermediate in character between the two kinds mentioned above, having neither the firmness of the one nor the mobility of the other. This is more especially the case in the junction between the head and the anterior segment of the thorax, and also between the last-named segment and the middle piece of the thorax, in those cases where these two parts are not joined by suture. The joint employed in this case is of very beautiful construction, resembling in some respects that formed by a ball and socket: a conical prolongation of one segment is admitted into a smooth cavity excavated in the corresponding margin of the other, and secured in this position by muscles and an external ligament. Such an articulation is of course capable of being firmly fixed by muscular action, but at the same time admits of sufficient freedom of motion to allow rotation in all directions.

(778.) The legs of insects, as we have already stated, are invariably six in number, one pair being attached to each of the three thoracic segments. Considered separately, every leg may be seen to consist of several pieces, connected together by articulations of different kinds, which require our notice. The first division of the leg, or that in immediate connexion with the thorax, to which it is united by a kind of ball-and-socket joint enclosed in a strong membranous capsule and possessing very various degrees of motion in different insects, is called the hip (*coxa*); and upon this, as upon a centre, the movements of the limb are performed. To the extremity of the *coxa* a small moveable piece is attached, called the *trochanter*; to which succeeds the thigh (*femur*), which is the thickest and most robust of all the divisions of the limb. The next piece, called the shank (*tibia*), is occasionally of considerable length, and is connected to the last by a hinge; to its extremity is appended the foot (*tarsus*), composed of a consecutive series of small segments, varying in number from five to one, the last of which is armed with claws, or other appendages, adapted to different kinds of progression. These divisions of the leg the reader will easily recognize; they are for the most part united together by articulations so constructed as to allow simply of flexion and extension, which will be best understood by inspecting, in some large insect, the junction between the femur and the tibia, or the knee-joint, as we might term it. Upon the upper extremity of the *tibia* the observer will find on each side a precise semicircular furrow, behind which is a concentrical but smaller ridge, and still further back a circular depression or fossulet. On examining the corresponding surfaces of the *femur*, he will detect a ridge accurately corresponding to the above-mentioned furrow; behind this, a furrow corresponding to the preceding ridge; and still further back, a minute elevation adapted to the fossulet of the tibia, wherein it is fastened by a minute but very strong ligament. Such ridges and grooves, when fitted into each other, form a joint evidently admitting of a free and hinge-like motion, while, from its structure, dislocation is almost impossible.

(779.) The above general description of the leg of an insect will prepare us to examine various modifications in outward form and mechanical arrangements by which these simple organs are adapted to progression under a great diversity of circumstances. When, indeed, we reflect how extensively this class of animals is distributed, and the variety of situations in which insects live, we are led to expect corresponding adaptations in the construction of their instruments of locomotion; and in this our expectations will not be disappointed.

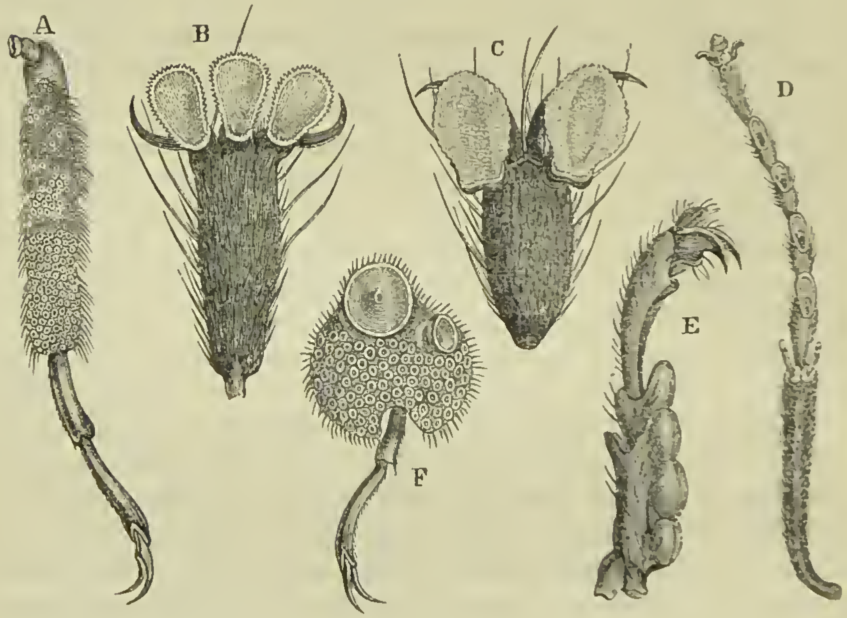
(780.) In the generality of terrestrial species, the last segment of the *tarsus* or foot is provided with a pair of strong horny hooks, which are available for many purposes, being used either for creeping upon a moderately rough surface, for climbing, or for clinging to various substances.

(781.) Such simple hooks, however, would not always serve. In the case of the louse (*Pediculus*) for example, that is destined to climb slender and polished hairs, such prehensile organs could be of little use.

The structure of the foot is therefore modified: the tarsus in this insect terminates in a single moveable claw, which bends back upon a tooth-like process derived from the tibia, and thus forms a pair of forceps, fitted to grasp the stem of the hair and secure a firm hold.

(782.) Many insects, especially those of the *Dipterous* order, are able to ascend the smoothest perpendicular planes, or even to run with facility, suspended by their feet, in an inverted position, along substances which, from their polished surfaces, could afford no hold to any apparatus of forceps or hooklets. In the common flies (*Muscidæ*), the exercise of this faculty is of such everyday occurrence, that, wonderful as it is, it scarcely attracts the attention of ordinary observers. The foot of the House-fly, nevertheless, is a very curious piece of mechanism; for, in addition to the recurved hooks possessed by other climbing species, it is furnished with a pair of minute membranous flaps (fig. 150, c), which, under a good microscope, are seen to be covered with innumerable hairs of the utmost delicacy: these flaps, or suckers, as they might be termed, adhere to any plane surface with sufficient tenacity to support the whole weight of the fly, and thus confer upon it a power of progression denied to insects of ordinary construction.

Fig. 150.



Feet of insects:—A, F, *Dytiscus*. B, *Bibio febrilis*. C, *Musca domestica*. D, *Cimbex lutea*. E, Abyssinian Grasshopper.

(783.) In *Bibio febrilis* (fig. 150, B), the sucking disks appended to the foot are three in number, but in other respects their conformation is the same.

(784.) In *Cimbex lutea* (fig. 150, D) the arrangement of the suckers is different, one large and spoon-shaped disk being attached to the extremity of each tarsal joint. Moreover, in this case there is another singular structure: two spur-like organs project from each side of the extremity of the tibia, each being provided with a sucking disk, while the two together form a strong prehensile forceps.

(785.) In some Water-beetles (*Dytiscidæ*) the feet are armed with a still more elaborately constructed apparatus of suckers; but in this case, as they are only met with in the male insect, they perhaps ought rather to be looked upon as a provision made for the purpose of securely holding the female during sexual union, than as being specially connected with locomotion.

(786.) In the anterior legs of the male *Dytiscus* the first three joints of the tarsus are excessively dilated, so as to form a broad circular palette: on examining the inferior surface of this expanded portion under a microscope, it is seen to be covered with an immense number of sucking-cups (fig. 150, F), two or three being much larger than the rest; but they form collectively a wonderful instrument of adhesion.

(787.) The middle pair of legs of the same beetle (fig. 150, A) exhibit a somewhat similar structure; but in this case the disk upon which the sucking apparatus is placed is much elongated, and the suckers are all of small dimensions.

(788.) In the female *Dytiscus* (fig. 152, c) this configuration of the tarsus is wanting; and moreover the surface of the back is marked with deep longitudinal grooves that do not exist in the male insect, but seem to be an additional provision for facilitating the intercourse of the sexes in these powerful aquatic beetles.

(789.) Another mode of progression common among insects is by leaping, to which, from their extraordinary muscular power, these little beings are admirably adapted. The common Flea, for example (*Pulex irritans*) (fig. 153), will leap two hundred times its own length; and many Orthoptera possess a power of vaulting through the air scarcely less wonderful, of which the Cricket affords a familiar instance. In such insects (fig. 145, A, B) the thighs of the posterior legs are enormously dilated, and the length of these limbs is much greater than that of the anterior pair. When disposed to leap, such insects bend each hind-leg, so as to bring the tibia into close contact with the thigh, which has often a longitudinal furrow, armed on each side with a row of spines, to receive it. The leg being thus bent, they suddenly unbend it with a jerk, when, pushing against the plane of position, they spring into the air*. In many of these saltatorial tribes the tarsus is furnished with very curious appendages, either provided for the purpose of obviating any jar when the animal alights from its lofty leaps†, or else they may act like firm cushions, adapted, by their elasticity, to give greater effect to the spring which raises the insect from the ground. In the magnified view of the tarsus of an Abyssinian Grasshopper (fig. 150, E) the arrangement of these organs is well exhibited.

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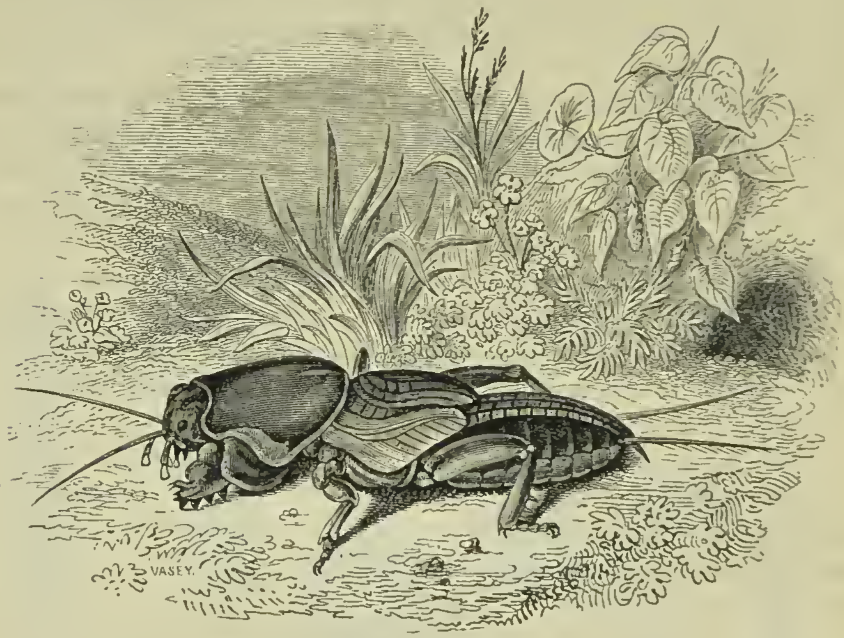
* Kirby and Spence, Introduction to Entomology, 4 vols. 8vo.

† Sir E. Home, Phil. Trans. 1816.

(790.) The next modification in the structure of the legs is met with in such species as burrow beneath the surface of the ground, of which mode of progression the most remarkable example is seen in the Mole-cricket (*Gryllotalpa vulgaris*) (fig. 151). In this creature, the anterior segment of the thorax, whereunto the fore-legs are appended, is wonderfully enlarged and of great strength, while the legs themselves are equally remarkable for their enormous bulk and muscularity. The tibia is excessively dilated, and terminates obliquely in four sharp and strong spines. The whole of the tarsus would, at a first glance, appear to be wanting; but on inspection it is found to consist of three joints placed upon the inner side of the tibia, the first two being broad and tooth-shaped, while the last piece is very small and armed with two hooks. The direction and motion of these hands is outwards, thus enabling the animal most effectually to remove the earth when it burrows; and, by the help of such powerful instruments, it is astonishing how rapidly it buries itself*.

Fig. 151.



Gryllotalpa vulgaris.

(791.) Similar examples of adaptation in the mechanical structure of the legs of insects might be multiplied indefinitely; we shall, however.

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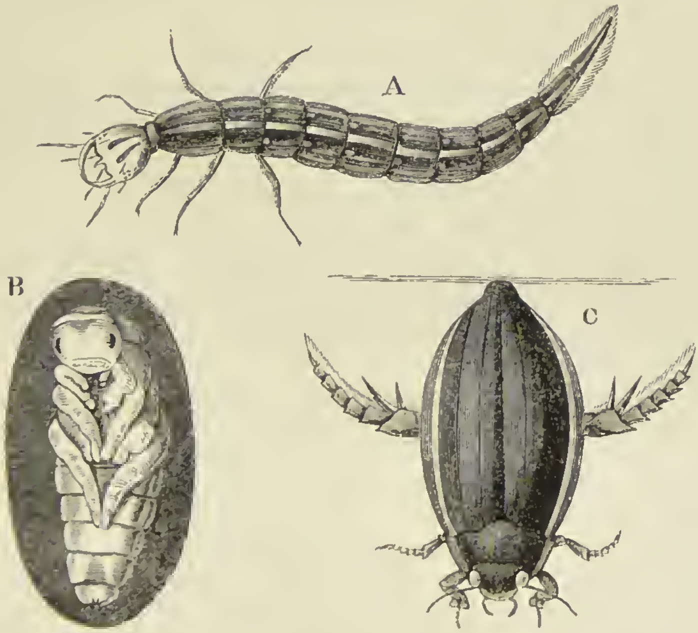
* Kirby and Spence, Introd. to Ent. vol. ii. p. 362.

select but one other illustration before leaving this part of our subject, namely the conversion of these organs into instruments for swimming, whereby, in aquatic insects, they become adapted to act as oars. Nothing is, perhaps, better calculated to excite the admiration of the student of animated nature than the amazing results obtained by the slightest deviations from a common type of organization; and in examining the changes required in order to metamorphose an organ which we have already seen performing such a variety of offices into fins adapted to an aquatic life, this circumstance must strike the mind of the most heedless observer. The limbs used in swimming exhibit the same parts, the same number of joints, and almost the same shape, as those employed for creeping, climbing, leaping, and numerous other purposes; yet how different is the function assigned to them! In a common Water-beetle already referred to, the *Dytiscus marginalis* (fig. 152, c), the two anterior pairs of legs, that could be of small service as instruments of propulsion, are so small as to appear quite disproportionate to the size of the insect, while the hinder pair are of great size and strength; the last-mentioned limbs are, moreover, removed as far backwards as possible, by the development of the hinder segment of the thorax, in order to approximate their origins to the centre of the body; and the individual segments composing them are broad and compressed, so as to present to the water an extensive surface, which is still further enlarged by the presence of flat spines appended to the end of the tibia,

Fig. 152.



Metamorphoses of *Dytiscus*.

as well as of a broad fringe of stiff hairs inserted all around the tarsus. The powerful oars thus formed can open until they form right angles with the axis of the body, and from the strength of their stroke are well adapted to the piratical habits of their possessors, who wage successful war, not only with other aquatic insects and worms, but even with small fishes, the co-inhabitants of the ponds wherein they live.

(792.) The same principles are carried out even more perfectly in the construction of the swimming-legs of the Water-boatman (*Notonecta*), a kind of water-bug. The resemblance of this creature (fig. 144, G, H) to a boat with its oars cannot escape the most inattentive examiner; and the similarity is still further increased by its manner of swimming; for, as it preys upon insects that have been accidentally drowned by falling into the water, it usually rows itself about upon its back, because in such a position it can best watch for its victims.

(793.) The wings of insects, when present, are invariably attached to the two posterior segments of the thorax, which, as we have already seen, are strengthened in every possible manner, so as to afford a support of sufficient density and firmness to sustain the violent exertions of the muscles inserted into the organs of flight.

(794.) In the most perfectly organized families the wings are four in number, as in the Neuroptera (fig. 146), the Hymenoptera (fig. 173), the Orthoptera (fig. 145), the Dictyoptera, the Hemiptera (fig. 144), the Lepidoptera (fig. 148), and the Coleoptera (fig. 149).

(795.) In the Dipterous insects there are only two wings, which are fixed upon the central segment of the thorax; while, in the position usually occupied by the posterior pair, we find a pair of pedunculated globular bodies, generally named the *halteres* or poisers, as in the Gnat (*Culex*) (fig. 177, F).

(796.) But, in every one of the orders above enumerated, there are certain families which, throughout the whole period of their existence, are never provided with wings at all; and these by many entomologists have been formed into an order by themselves, under the name of *Apterous* insects. In the opinion of Burmeister*, whose classification we have adopted, such an arrangement is purely artificial, inasmuch as it must embrace insects of most dissimilar kinds. In proof of this, he adduces the fact that, in the same family, we not unfrequently meet with both winged and apterous species, nearly related to each other; and in many cases the males possess wings, while the females of the same insect are entirely destitute of such appendages. In such cases, the metamorphosis is necessarily what is called *incomplete*, inasmuch as the organs which characterize the perfect state are not developed. Thus, in the Flea (*Pulex irritans*) (fig. 153) the wings never become apparent, and in consequence the *thorax*, even in the imago state, does not exhibit that development and consolidation of its parts invariably met with in winged genera. The Flea, however, cannot on this account be looked upon as any other than the imago or complete insect, for it will be found to have undergone all the preparatory changes. The Flea, when it issues from the egg, is in fact a worm-like and footless larva, in which condition it lives about twelve days. When about to become a pupa, it spins for itself a little silky cocoon, wherein it conceals itself until, having thrown off its last skin, it appears in its mature form, deprived indeed of wings, that, under the circumstances in which it lives, would be useless appendages, but still, with this exception, corresponding in every particular with other insects in their imago state.

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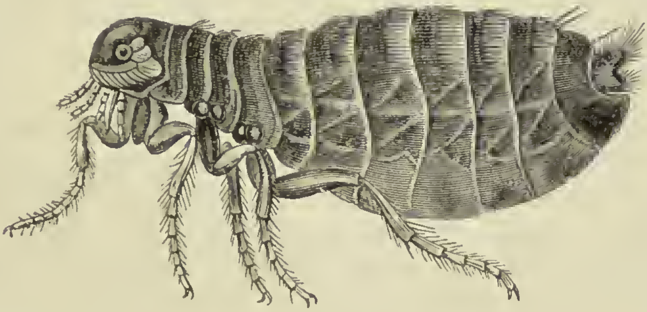
* Manual of Entom. p. 623.

Fig. 153.



Pulex irritans.

(797.) The wings of insects differ much in texture. In the *Neuroptera*, by far the most powerful fliers met with in the insect world, all four wings are of equal size, and consist of a thin membranous expansion of great delicacy and of a glassy appearance, supported at all points by a horny network (fig. 146). Few things are met with in nature more admirable than these structures; they present, indeed, a combination of strength and lightness absolutely unequalled by anything of human invention; and as instruments of flight they far surpass the wings of birds, both in the power and precision of their movements, inasmuch as these insects can fly in all directions—backwards, or to the right or left, as well as forwards. Leeuwenhoek[*] narrates a remarkable instance in which he was an eye-witness of the comparative capabilities of the Dragon-fly and the Swallow, as relates to the perfection of their flight. The bird and the insect were both confined in a menagerie about a hundred feet long, and apparently their powers were fairly tested. The swallow was in full pursuit; but the little creature flew with such astonishing velocity, that this bird of rapid flight and ready evolution was unable to overtake and entrap it,—the insect eluding every attempt, and being generally six feet before it. "Indeed," say the authors from whom we quote the above anecdote[†], "such is the power of the long wings by which the Dragon-flies are distinguished, and such the force of the muscles which move them, that they seem never to be wearied with flying. I have observed one of them (*Anax imperator*, Leach) sailing for hours over a piece of water—sometimes to and fro, and sometimes wheeling from side to side, and all the while chasing, capturing, and devouring the various insects that came athwart its course, or driving away its competitors—without ever seeming tired or inclined to alight."

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[*] Epist. 6, Mart. 1717.

[†] Kirby and Spence, *op. cit.* vol. ii. p. 351.

(798.) In Hymenopterous insects (figs. 171 and 173) the wings are much more feebly organized, but their structure is similar. The nervures, or horny ribs supporting the membranous expansion, are comparatively few; and in the Diptera they are still less numerous.

(799.) In several orders the anterior pair of wings are converted into shields for the protection of the posterior; such is the case in the Orthoptera, many of the Hemiptera, and more especially in the Coleopterous genera. In the latter, indeed, they are very dense and hard; and, being nearly unserviceable in flight, the hinder pair are necessarily developed to such a size as to present a very extensive surface (fig. 149, A), and when in repose are closely folded up beneath the elytra, and thus carefully preserved from injuries, to which they would be constantly exposed without such provision for their security.

(800.) The above observations relate only to the general disposition and connexion of the different parts of the skeleton, and locomotive appendages connected with it; it remains for us now to speak more fully of the texture of the external integument, and those modifications which it presents, adapting it to various purposes.

(801.) The hard covering of an insect, like the skin of vertebrate animals, consists of three distinct layers. The outer stratum, or *epidermis*, is smooth, horny, and generally colourless, so that it forms a dense inorganic film spread over the whole surface of the body. Immediately beneath the epidermis is a soft and delicate film, the *rete mucosum*, which is frequently painted with the most lively hues, and gives the characteristic colouring to the species. The third and principal layer is the true skin, or *cutis*, which is generally of a leathery texture, and, especially in the elytra of Beetles, of considerable thickness: this layer is abundantly supplied with nutritive juices; and in its substance the bulbs of hairs, scales, and similar appendages, to be described hereafter, are imbedded and nourished.

(802.) The wings are mere derivations from this common covering, and are composed of two delicate films of the epidermis, stretched upon a strong and netlike framework. Every membranous wing is, in fact, a delicate bag formed by the epidermic layer of the integument, and in the recently-developed insect can be distinctly proved to be such by simply immersing the newly-escaped imago in spirit of wine, which gradually insinuates itself between the still fresh and soft membranes, and, filling the cavity enclosed between them, distends the organ until it represents a transparent sacculus, in which the ribs or nervures of the wing are enclosed*. This structure, however, is only to be displayed while the wings, after being withdrawn from the pupa-case, are still soft and moist; for they soon become so intimately united with the horny framework upon which they are extended, that they seem to form a single membranous expansion.

(803.) The ribs, or nervures, whereby the two plates of the wing are thus supported, are slender hollow tubes, filled with a soft parenchyma: in the interior of some, Burmeister detected an air-vessel (recognizable by the texture of its walls) and a minute nervous filament.

(804.) We have still, in order to complete our description of the external anatomy of an insect, to describe certain appendages which not unfrequently clothe the exterior of the skeleton, and exhibit great diversity of appearance in different tribes. These may be divided into *spines, hairs,* and *scales*; and, however much they may appear to be distinct structures, all these are essentially very nearly related to each other.

(805.) The *spines* are horny processes developed from the epidermis; and sometimes, especially in the Coleopterous order, as in some lamellicorn Beetles, exhibit considerable dimensions. These spines are sometimes bifurcated or branched; but, whatever their shape or size, they never grow from bulbs implanted in the cutis, but are mere prolongations of the exterior layer of the integument.

(806.) The *hairs* appear to resemble those of quadrupeds in their mode of growth, inasmuch as they are secreted from roots imbedded in the substance of the cutis or true skin: they are fine horny cylinders, and frequently are found to be branched and divided like the feathers of birds; but the manner of their formation will be more conveniently discussed hereafter.

(807.) The wings of the *Lepidoptera* are covered with minute flat scales of various shapes, and not unfrequently tinted with the most beautiful colours; such scales, nevertheless, are in reality only flattened hairs, into which, indeed, they frequently degenerate by insensible transitions; and, moreover, they grow from bulbs of precisely similar construction. The variety of colours exhibited by the scales of a Butterfly depends upon a film of pigment interposed between the two plates of transparent epidermic matter forming each; but the gorgeous hues derived from this source must not be confounded with the iridescent tints for which they are not unfrequently remarkable, as these have a very different origin: the surface of every scale, that with the changing light reflects evanescent prismatic colours, is seen, when examined under a microscope, to be marked with regular parallel striæ of exquisite minuteness; and such a surface, even when grossly imitated by human art, has been found to give rise to the brilliant appearances exhibited by polarized light.

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* Heusinger, System der Histologie, 2. Heft. Burmeister, *op. cit.* p. 224.

(808.) The muscular system of insects has always excited the wonder and astonishment of the naturalist, in whatever point of view he examines this part of their economy—whether he considers the perfection of their movements, the inconceivable minuteness of the parts moved, or the strength, persistence, or velocity of their contractions. Insects are proverbially of small comparative dimensions—“ minims of nature,”

> . . . . . “ that wave their limber fans
> For wings, and smallest lineaments exact,
> In all the liveries deck'd of summer's pride ;”

their presence, indeed, around us is only remarked as conferring additional life and gaiety to the landscape ; and except when, by some inordinate increase in their numbers, they make up by their multitude for their diminutive size, the ravages committed by them are trifling and insignificant. Far otherwise, however, would it be if they attained to larger growth, and still possessed the extraordinary power with which they are now so conspicuously gifted ; they would then, indeed, become truly the tyrants of the creation—monsters such “ as fables never feigned or fear conceived ”—fully adequate to destroy and exterminate from the surface of the earth all that it contains of vegetable or of animal life.

(809.) We have already seen that the Flea or the Grasshopper will spring two hundred times the length of its own body ; that the Dragonfly possesses such indomitable strength of wing, that for a day together it will sustain itself in the air, and fly with equal facility and swiftness backwards or forwards, to the right or to the left, without turning ; that the Beetles are encased in a dense and hard integument, impervious to ordinary violence; and we might add that the Wasp and the Termite Ant will penetrate with their jaws the hardest wood. Neither is the velocity of the movements of insects inferior to their prodigious muscular power. “ An anonymous writer in Nicholson's Journal,” say Kirby and Spence, “ calculates that in its ordinary flight the common House-fly (*Musca domestica*) makes with its wings about six hundred strokes, which carry it 5 feet, every second ; but if alarmed, he states their velocity can be increased six- or seven-fold, or to 30 or 35 feet in the same period. In this space of time a race-horse could clear only 90 feet, which is at the rate of more than a mile a minute. Our little Fly, in her swiftest flight, will in the same space of time go more than the third of a mile. Now, compare the infinite difference of the size of the two animals (ten millions of the Fly would hardly counterpoise one racer), and how wonderful will the velocity of this minute creature appear ! Did the Fly equal the race-horse in size, and retain its present powers in the ratio of its magnitude, it would traverse the globe with the rapidity of lightning*.”

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* Kirby and Spence, *op. cit.* vol. ii. p. 358.

(810.) Let the reader, therefore, imagine for an instant that great law of nature, which restricts the dimensions of an insect within certain bounds, dispensed with even in a single species. Suppose the Wasp or the Stag-beetle dilated to the bulk of a tiger or of an elephant—cased in impenetrable armour—furnished with jaws that would crush the solid trunk of an oak—winged, and capable of flight so rapid as to render escape hopeless; what would resist such destroyers? or how could the world support their ravages?

(811.) Such is the comparative strength of insects. Let us now proceed to examine the muscles to which it is owing, their structure and general arrangement.

(812.) The muscles consist of bundles of delicate fibres, that arise either from the inner surface of the segments composing the skeleton, or else from the internal horny septa which project into the thorax. The fibres themselves are of a white or yellow colour; and so loosely are they connected by cellular tissue, that they may be separated by the slightest touch.

(813.) All the muscles of an insect may be arranged in two great divisions: the first including those that unite the different segments of the body; the second, those appropriated to the movements of the limbs, jaws, and other appendages. The former are entirely composed of fleshy fibres; the latter are provided with tendinous insertions, by which their force is concentrated and made to act with precision upon a given point of the skeleton.

(814.) The *connecting* muscles are generally arranged in broad parallel bands, arising from the inner surface of a given segment, and passing on to be inserted in a similar manner into another segment, so that by their contraction the cavity in which they are lodged is diminished by the approximation of the different rings: these have no tendons.

(815.) The *locomotive* muscles, of course, take their character from the joints of the limb upon which they act; and as we have already seen that these movements are generally confined to those of a hinge, the muscular fasciculi may be conveniently grouped into two great classes—the *flexor* muscles, that bend the joint, and the *extensors*, by which it is again straightened, and brought back to its former position. This simple arrangement will be best understood by an inspection of fig. 154, representing the muscles of the leg of a Cockchafer (*Melolontha vulgaris*), as they are depicted by Straus-Durckheim*. In the thigh, for example, there are two muscles, one of which bends, the other straightens, the tibia. The flexor (fig. 154, *a*) arises from the lining membrane of the femur, and is inserted by a tendon into a process of the tibia in such a manner as to flex the leg upon the thigh; while its antagonist (*b*), attached to a process derived from the other side of

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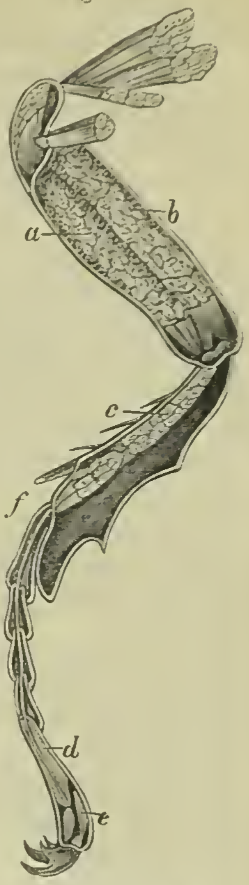
* Considérations générales sur l'Anatomie comparée des Animaux articulés, auxquelles on a joint l'Anatomie descriptive du Hanneton. 1 vol. 4to. Paris, 1828.

the joint, has an opposite effect, and by its contraction extends the leg. In the tibia there are likewise two muscles, so disposed as to move the entire *tarsus* and foot. The *extensor* (*f*) of the tarsus is the smallest; it arises from the lower half of the interior of the tibia, and is inserted into the margin of the first joint of the *tarsus*: but the flexor of the foot (*c*), arising from the upper half of the cavity of the tibia, ends in a delicate tendon, which passes through all the tarsal segments, to be fixed to the flexor tendon of the claw-joint, upon which it acts; and as it traverses the penultimate joint it receives the fibres of an accessory muscle (*d*). The *extensor* of the claw (*e*) is likewise placed in the penultimate tarsal segment, and strikingly exhibits, by its small comparative size, the feebleness of its action when compared with that of the flexors of the same joint.

(816.) It would be superfluous to describe more in detail the disposition of individual muscles, as the above example will abundantly suffice to give the reader an idea of the general arrangement of the muscular system, not in insects only, but in all the ARTICULATA provided with jointed extremities.

Fig. 154.

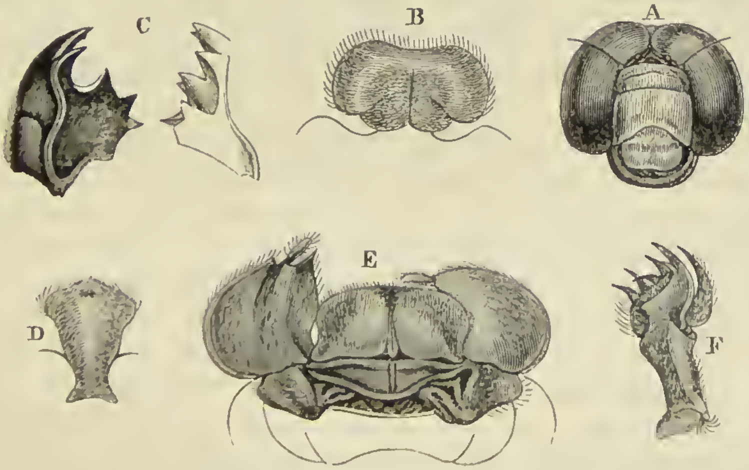


Muscles of the leg of a Cockchafer.

(817.) The substances employed as food by insects are various, in proportion to the extensive distribution of the class. Some devour the leaves of vegetables, or feed upon grasses and succulent plants; others destroy timber, and the bark or roots of trees; while some, more delicately organized, are content to extract the juices of the expanding buds, or sip the honeyed fluids from the flowers. Many tribes are carnivorous in their habits, armed with various weapons of destruction, and carry on a perpetual warfare with their own or other species; and again, there are countless swarms appointed in their various spheres to attack all dead and putrefying materials, and thus to assist in the removal of substances which, by their accumulation, might prove a constant source of annoyance and mischief. Such differences in the nature of their food demand, of course, corresponding diversity in the construction of the instruments employed for procuring nourishment; and accordingly we find, in the structure of the mouths of these little beings, innumerable modifications adapting them to different offices. The mouths of all creatures are constructed upon purely mechanical principles; and in few classes of the animal world have we more beautiful illustrations of design and contrivance than in that before us: jaws armed with strong and penetrating hooks for seizing and securing active and struggling prey—sharp and powerful shears for clipping and dividing the softer parts of vegetables—saws, files, and augers for excavating and boring the harder parts of plants—lancets for piercing the skin of living animals—siphons and sucking-tubes for imbibing fluid nutriment—all these, in a thousand forms, are met with in the insect world, and thus provide them with the means of obtaining food adapted to their habits, and even of constructing for themselves edifices of inimitable workmanship.

(818.) *Parts of the mouth.*—The mouths of insects may be divided into two great classes:—those which are adapted for biting, forming what is called a *perfect* or *mandibulate* mouth; and those which are so constructed as only to be employed in sucking, constituting the *suctorial, haustellate* mouth. It is in the former of these divisions that all the parts composing the oral apparatus are most completely developed; we shall therefore commence by describing the different pieces of which a perfect mouth consists, viz. an upper and an under lip, and four horny jaws. We select the mouth of the Dragon-fly (fig. 155, A) as an example. The upper lip (*labrum*, B) is a somewhat convex corneous plate, placed transversely across the upper margin of the cavity wherein the jaws are lodged, so that, when the mouth is shut, it folds down to meet the under lip (*labium*), and these two pieces more or less completely conceal the proper jaws, which are lodged between them.

Fig. 155.



Parts of the mouth of a Dragon-fly.

(819.) The upper pair of jaws (*mandibulæ*) are two hard and powerful hooks (fig. 155, C), placed immediately beneath the upper lip, and so articulated with the cheeks that they move horizontally, opening and shutting like the blades of a pair of scissors. Their concave edge is armed with strong denticulations of various kinds, sometimes furnished with cutting edges that, like sharp shears, will clip and divide the hardest animal and vegetable substances; sometimes they form sharp and pointed fangs, adapted to seize and pierce their victims; and not unfrequently they constitute a series of grinding surfaces, so disposed (like the molar teeth of quadrupeds) as to triturate and bruise the materials used as food. The variety of uses to which these mandibles can be turned is indeed amazing. In the carnivorous Beetles, their hooked points, more formidable than the teeth of the tiger, penetrate with ease the mailed covering of their stoutest congeners; and in the Dragon-fly they are scarcely less formidable weapons of destruction. In the Locust tribes these organs are equally efficient agents in cutting and masticating leaves and vegetable matters adapted to their appetites; while in the Wasps and Bees they form the instruments with which these insects build their admirable edifices, and, to use the words of a popular author, supply the place of trowels, spades, pickaxes, saws, scissors, and knives, as the necessity of the case may require.

(820.) Beneath the *mandibles* is situated another pair of jaws, of similar construction, but generally smaller and less powerful; these are called the *maxillæ* (fig. 155, F).

(821.) The lower lip, or *labium* (fig. 155, E), which closes the mouth inferiorly, consists of two distinct portions, usually described as separate organs,—the chin (*mentum*), that really forms the inferior border of the mouth; and a membranous or somewhat fleshy organ, reposing upon the chin internally, and called the *tongue* (*lingua*) of the insect (D).

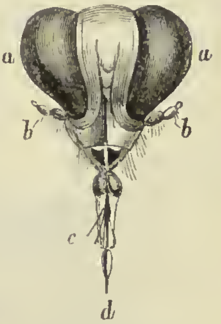
(822.) All these parts enter into the composition of the perfect mouth of an insect, and, from the numerous varieties that occur in their shape and proportions, they become important guides to the entomologist in the determination and distribution of species. For more minute details concerning them, the reader is necessarily referred to authors who have devoted their attention specially to this subject; we must not, however, omit to mention certain appendages or auxiliary instruments inserted upon the *maxillæ* and the *labium*, usually named the *palpi*, or feelers, and most probably constituting special organs of touch, adapted to facilitate the apprehension and to examine the nature of the food. The *maxillary feelers* (*palpi maxillares*) are attached to the external margin of the maxillæ by the intervention of a small scale and very pliant hinge, and consist of several (sometimes six) distinct but extremely minute pieces articulated with each other. The *labial feelers* (*palpi labiales*) are inserted into the *labium* close to the tongue, or occasionally upon the chin (*mentum*) itself. The joints in the labial palpi are generally fewer than in the maxillary, but in other respects their structure and office appear to be the same.

(823.) In the suctorial orders of insects we have the mouth adapted to the imbibition of fluid nutriment, and consequently constructed upon very opposite principles; yet, notwithstanding the apparent want of resemblance, it has been satisfactorily demonstrated by Savigny* that the parts composing a suctorial mouth are fundamentally the same as those met with in the mouths of mandibulate insects, but transformed in such a manner as to form a totally different apparatus.

(824.) According to the distinguished authors of the 'Introduction to Entomology†,' there are five kinds of imperfect mouth adapted to suction, each of which will require a separate notice.

(825.) The first is met with among the *Hemiptera*, and is formed to perforate the stalks and buds of vegetables, in order to procure the juices which they contain; or, in some bugs, it is employed to puncture the integument of living animals for a similar purpose. This kind of mouth is exhibited in fig. 156. First, there is a long jointed sheath (*d*), which is in fact the lower lip (*labium*) considerably elongated, and composed of three or four parts articulated together; secondly there is a small conical scale covering the base of the sheath last mentioned, and representing the upper lip; and between these are four slender and rigid bristles or lancets (*scalpella*) (*c*), that, when not in use, are lodged in a groove upon the upper surface of the sheath, so as to be concealed from view. These lancets are, in reality, only the mandibles and maxillæ strangely altered in their form and excessively lengthened, so as not merely to become efficient piercing instruments, but so disposed as to form by their union a suctorial tube, through which animal or vegetable fluids may be imbibed. This kind of mouth, when not employed, is usually laid under the thorax, between the legs, in which position it is easily seen in most Hemiptera. In some families, as, for example, in the Plant-lice (*Aphides*), it is of extraordinary length: thus, in the *aphis* of the oak it is three times as long as the whole body of the insect, projecting posteriorly like a tail; and in the *fir-aphis* it is still longer.

Fig. 156.



Mouth of *Notonecta*.

(826). The second kind of mouth is that met with among the *Diptera*; and from its construction in some tribes, we may well understand how they are enabled to become so seriously annoying. The Gnat and the Mosquito furnish sufficiently well-known examples of the formidable apparatus in question, which in the Horse-fly (*Tabanus*) seems to attain its maximum of development. The oral organs of the *Diptera* are composed of a sheath or proboscis, that represents the lower lip of the mandibulate insects: it is sometimes coriaceous or horny in its texture;

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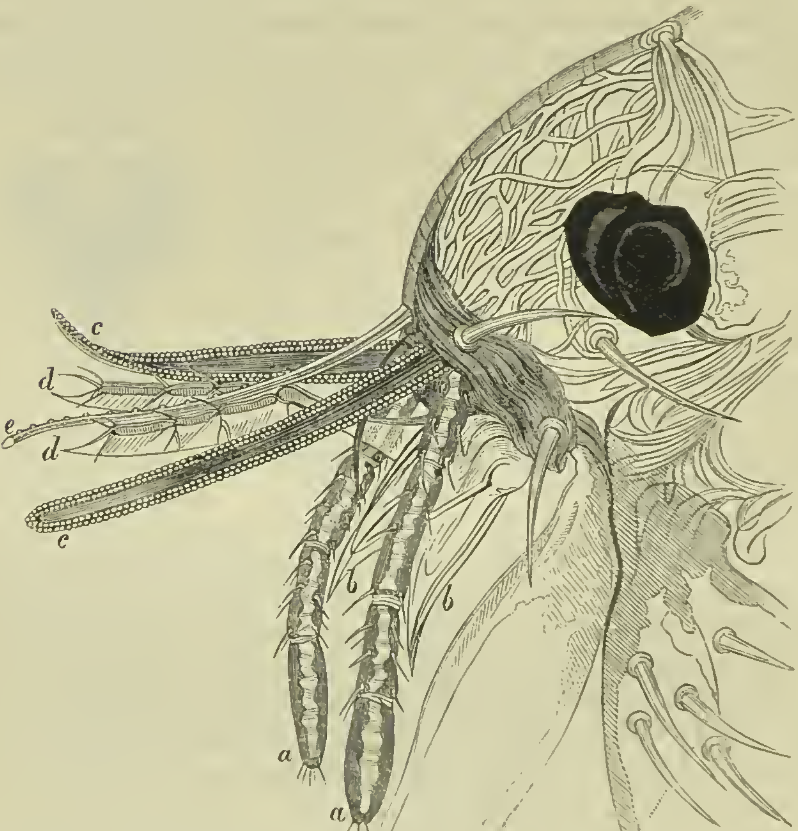
* Mémoires sur les Animaux sans Vertèbres. 8vo. Paris, 1816.

† Kirby and Spence, vol. iii. p. 463.

in other cases, as in the common Flesh-fly, soft and muscular, and folds up when at rest in such a manner as to form two angles, representing the letter Z. At the base of this sheath or proboscis there is a small upper lip, between which and the sheath are lodged the setæ, knives, or lancets, which form such terrible instruments for cutting or piercing the skin of their victims. These cutting parts vary in number from one to five: when they are all present, the upper pair (*cultelli*, or knives) represent the mandibles of a perfect mouth, the two lower ones (*scalpella*, the lancets) are the maxillæ, the fifth or middle piece (*glossarium*) is the tongue; and between them all is the oral opening. The strength of the above piercing instruments varies greatly: in the Gnat they are finer than a hair, very sharp, and barbed occasionally on one side; while in the Horse-fly they are flat, like the blades of a lancet or

Fig. 157 *.



Head of a Flea.

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* Head of the Flea, as represented by the Solar microscope in Canada balsam: dedicated by permission to the President and Members of the Entomological Society, by W. Lens Aldous.

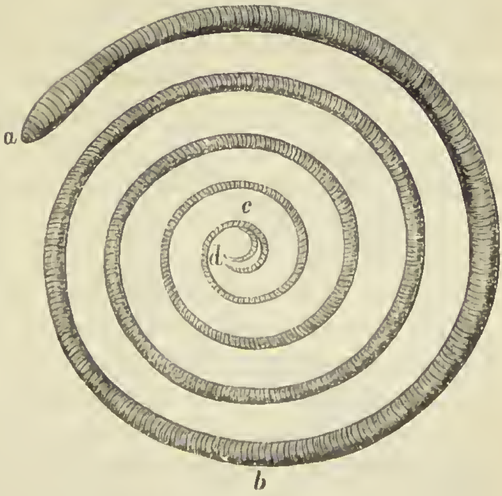
penknife; occasionally they are so constructed as to form a tube by their union, through which the liquid aliment is sucked up and conveyed into the stomach.

(827.) The mouth of the Flea, although described by Kirby and Spence as forming a distinct type of structure, differs very little from that of the Diptera described above, as will be at once evident on inspecting the figure in the preceding page, reduced from a beautiful drawing by Mr. W. Lens Aldous.

(828.) In this insect the piercing organs are two sharp and razor-like instruments (fig. 157, *d d*), placed on each side of the elongated tongue (*e*), and enclosed in a sheath (*c c*), probably formed by pieces representing the mandibles of mandibulate insects. Two *palpi* or feelers (*a a*) and a pair of triangular plates (*b b*) complete this remarkable apparatus.

(829.) Another kind of mouth adapted to suction, and which seems to differ more widely from the perfect form than any we have as yet examined, is that which we meet with in Moths and Butterflies. This singular organ is adapted to pump up the nectareous juices from the cups of flowers, and is necessarily of considerable length, in order to enable the insect to reach the recesses wherein the honeyed stores are lodged. When unfolded, the apparatus in question represents a long double whip-lash (fig. 158, *a*, *b*, *c*, *d*); and if carefully examined under the microscope, each division is found to be made up of innumerable rings connected together, and moved by a double layer of spiral muscular fibres, that wind in opposite directions around its walls. When not in use, the proboscis is coiled up and lodged beneath the head; but when uncurled, its structure is readily examined. Each of the two long filaments composing this trunk (which, in fact, are the representatives of the *maxillæ* excessively lengthened) is then seen to be tubular; and, when they are placed in contact, it is found that their edges lock together by means of minute teeth, so as to form a central canal leading to the orifice of the mouth. It is through this central tube, formed by the union of the two lengthened maxillæ, that fluids are imbibed. Burmeister, however, asserts that the cavities contained in each division

Fig. 158.



Mouth of a Butterfly.

likewise communicate with the commencement of the œsophagus, so that the Lepidoptera have, as it were, two mouths, or rather two separate methods of imbibing nourishment—one through the common canal formed by the junction of the whip-like jaws, the other through the cavities of the filiform maxillæ themselves; such an arrangement, however, which would be quite anomalous, may reasonably be doubted. In this mouth, therefore, all the parts, except the maxillæ, would seem at first sight to be wanting; they may nevertheless be detected upon a very careful examination, and rudiments of the upper lip, of the mandibles, of the lower lip, as well as of the labial and maxillary palpi, be distinctly demonstrated.

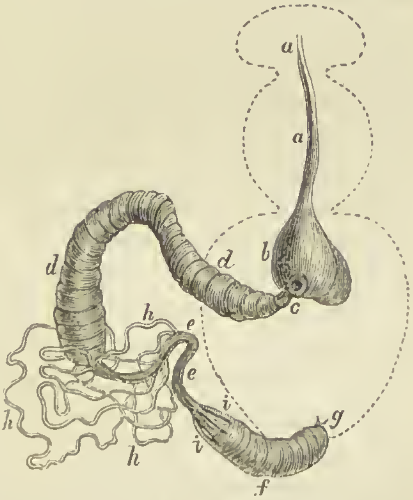
(830.) The last kind of mouth to which we shall advert is that met with in the Louse tribe (*Pediculi*); but, from the extreme minuteness of the parts composing it, the details of its structure are only imperfectly known. It seems to consist of a slender external tube, wherein a sharp sucker, armed with barbs adapted to fix it securely during the act of sucking, is lodged; when feeding, the barbed piercer is denuded and plunged into the skin, where it is retained until a sufficient supply of nourishment has been obtained.

(831.) Inviting as the subject is, we are compelled, by the strictly general character of our investigations, to abstain from entering upon further details concerning the mouths of perfect insects, and consequently to omit noticing innumerable secondary modifications in the mechanical structure of the oral organs of these little animals. When we turn our attention to the consideration of their internal viscera, connected with the preparation and digestion of so many different materials, we may well expect to find equal variety of conformation; and, in fact, the course, dimensions, and relative proportions of the alimentary canal will be seen to be different, to a greater or less extent, in almost every species. Considered as a whole, the internal digestive apparatus of insects must be regarded as a delicate membranous tube, in which the digestion of the substances used as food is accomplished partly by mechanical and partly by chemical agency. For the former purpose, gizzard-like muscular cavities are not unfrequently provided; and to fulfil the second, various fluids are poured into the canal in different parts of its course. The arrangement of the cavities and the nature of the secreting vessels will, however, be modified in conformity with the necessities of the case, and certain parts will be found to exist, or to be deficient, as circumstances may require; it would be absurd, therefore, to attempt to describe particular examples: our observations must be of general application, and such as will enable the reader to assign its proper function to any organ which may present itself to his notice. The first part of the digestive apparatus is disposed in the same manner in all insects, and is a slender canal arising from the mouth and passing straight through the thorax into the cavity of the abdomen: this portion represents the œsophagus (fig. 159, *a a*; fig. 160, *o*). The stomach and intestine succeed to this; and if the body of the insect be very thin, their course also passes nearly in a direct line to the tail. But in those families which have the abdomen thick and largely developed, especially if herbivorous, the intestine becomes much elongated and winds upon itself in various convolutions; nevertheless, however tortuous the canal may be, its windings are never sustained by any mesentery or peritoneal investment: the air-tubes (that, as we shall afterwards see, permeate the body in all directions) form a sufficient bond of connexion, and one which is better adapted to the wants of these animals.

(832.) We must now examine more minutely the different portions of which the alimentary canal may consist, premising at the same time that the structures mentioned do not invariably exist together, as sometimes one part and sometimes another may be entirely wanting, or only found in a very rudimentary condition. They are, the *crop*, the *gizzard*, the *stomach*, the *small intestine*, and the *large intestine*.

(833.) The *crop*, or *sucking-stomach*, as it is called by some writers, is only met with in Hymenoptera, Lepidoptera, and Diptera—insects which have no gizzard*. In Bees, Wasps, and other Hymenoptera, it is a simple bladder-like distention of the œsophagus (fig. 159, *b*); in Butterflies and Moths it forms a distinct bag, that opens into the side of the gullet (fig. 160, *v v*); while in the Diptera it is a detached vesicle, appended to the œsophagus by the intervention of a long thin duct. This organ, which in Bees is usually called the honey-bladder, is regarded by Burmeister (who founds the opinion upon the result of experiments made by Treviranus upon living insects) as being not merely a receptacle for food, resembling the craw of birds, as Ramdohr† and Meckel consider it, but as being a sucking instrument for imbibing liquids, by becoming distended, as he expresses it, and thus, by the rarefaction of the air contained within it, facilitating the rise of the fluids in the proboscis and œsophagus. It must, however, be confessed that there is something very anomalous in the

Fig. 159.



Alimentary canal of the Honey Bee, *Apis mellifica*. *a a*, œsophagus; *b*, the crop or sucking-stomach; *c*, *d d*, the stomach proper; *e e*, small intestine; *f*, large intestine; *g*, anal orifice; *h h*, biliary vessels; *i i*, auxiliary glands.

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* Burmeister, *op. cit.* p. 125. Treviranus, Vermischte Schriften.

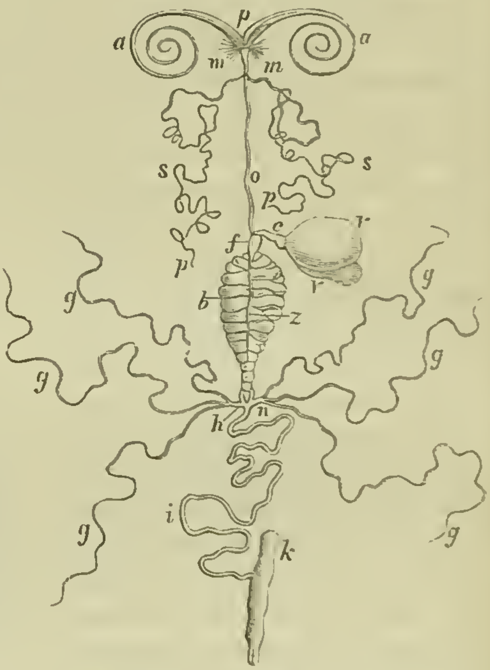
† Ramdohr, Ueber die Verdauungswerkzeuge der Insekten. Halle, 1811.

idea of a delicate bag having the power of distending itself: its muscular walls might indeed *contract*; but that a thin sacculus should forcibly *expand* itself would be a fact new to physiology.

(834.) The *gizzard* is found in insects which possess mandibles and live upon solid animal or vegetable substances. It is a small round cavity with very strong muscular parietes, situated just above the stomach properly so called, and, like the gizzard of granivorous birds, is employed for the comminution of the food preparatory to its introduction into the digestive stomach. In order to effect this, it is lined internally with a dense cuticular membrane, and occasionally studded with hard plates of horn, or strong hooked teeth, adapted to crush or tear in pieces whatever is submitted to their action.

(835.) When bruised in the gizzard, the food passes on into the proper stomach, which is generally a long intestiniform organ (fig. 159, *d d*), extending from the crop or gizzard to the point where the biliary vessels discharge themselves into the intestine. The size and shape of this organ will vary, of course, with the nature of the food. Thus, in the Butterfly, which scarcely eats at all, or sparingly sips the honey from the flowers, it is very minute (fig. 160, *b*); but in insects which live upon coarse and indigestible materials, it is proportionately elongated and capacious.

Fig. 160.



Alimentary canal of a Butterfly: *a a*, proboscis; *p*. mouth; *m m*, pharynx; *s p*, *s p*, salivary glands; *o*. œsophagus; *r r*, crop. communicating by a canal (*c. f*) with the stomach proper (*b*, *z*); *i*. small intestine; *k*. large intestine; *g g g*, hepatic vessels; *h*, *n*, their terminations in the vicinity of the pylorus.

(836.) The stomach generally ends in the *small intestine* (fig. 159, *e*; fig. 160, *i*); but this is occasionally entirely wanting, so that the stomach seems to terminate immediately in the *colon* or large intestine, which is the terminal portion of the alimentary canal: when much developed, the small intestine is sometimes divided by a constriction into two parts, to which the names of *duodenum* and *ilium* have been applied by entomological writers. The colon (fig. 159, *f*: fig. 160. *k*) is separated from the small intestine by a distinct valve; and in connexion with its commencement a wide blind sacculus or cæcum is often met with.

(837.) We may now notice the secerning organs that pour fluids into different parts of the digestive apparatus, beginning with those which open into the œsophagus in the vicinity of the mouth, and examining them in the order of their occurrence as we proceed backwards.

(838.) The first are the *salivary vessels*, which terminate in the neighbourhood of the mouth itself, into which they seem to pour a secretion analogous to saliva. These glands are principally met with in suctorial insects, but not unfrequently among the mandibulate orders. Their form varies; but they are generally simple slender tubes, that float loosely among the juices of the body, from which they separate the salivary fluid. There are, for the most part, only two of these organs (fig. 160, *s s*); but in fleas (*Pulex*) and bugs (*Cimex*) there are four, and in a water-bug (*Nepa*) there are six such vessels, all of which open into the cavity of the mouth. The fluid supplied by the salivary glands is usually merely intended to facilitate deglutition; but there are cases in which the saliva is excessively acrid and irritating, acting as a kind of poison when infused into a puncture made by the mouth: this is especially remarkable in many bugs and gnats, and is the chief cause of the pain and inflammation frequently occasioned by their bite.

(839.) Besides the proper salivary vessels, there are other glands, or rather cæca, which open into the stomach itself, occasionally covering that organ over its entire surface, as is the case in some water-beetles (*Hydrophilus*): these, no doubt, secrete a fluid subservient to digestion; but whether of a peculiar description, or allied to saliva in its properties, is unknown.

(840.) The third kind of auxiliary vessels connected with the intestinal canal of insects are supposed to furnish a secretion analogous to the bile of other animals, and consequently to represent the liver. These *bile-vessels* (fig. 159, *h h*; fig. 160, *g g*) are generally four, six, or eight in number, but occasionally much more numerous; they are usually of great length, but exceedingly slender, and wind around the intestine in all directions. When unravelled, they are found to terminate in the neighbourhood of the pylorus (fig. 160, *h*, *n*), close to the commencement of the intestine, at which point the secretion produced by them is mixed with the food after it has undergone the process of digestion.

(841.) Appended to the termination of the alimentary tube, close to its anal extremity, other vessels are met with in some insects, that are looked upon by authors as being allied in function to the kidneys of higher animals; but apparently this opinion rests upon very doubtful grounds. They indubitably furnish some secretion, the use of which is perhaps connected with defecation; but that it is of the same character as the fluid separated by the renal organs of Vertebrata may well be called in question, as no such parts are distinctly recognizable until we arrive at much more elevated forms of life than the insects we are now considering. There is, however, another reason for rejecting the opinion that these accessory vessels secrete urine; and that is, that they are only met with in a few beetles and some species of Orthoptera—a circumstance that alone would be sufficient to disprove such a supposition.

(842.) In the vertebrate animals, as the reader is well aware, the nutritious products of digestion are taken up by a system of absorbing vessels that ramify extensively over the coats of the intestine; and the nutriment is thus conveyed into the mass of the circulating fluid by ducts appropriated specially to this office: in animals of less perfect structure than these, such as the Mollusca, the veins themselves absorb the nutritive materials. But in insects, in which we find neither absorbents nor veins, a different arrangement is necessary, and, in the little creatures before us, nutrition appears to be carried on by the simple transudation of the chyle through the coats of the intestine; so that it escapes into the general cavity of the abdomen, where, as we shall see when we examine the arrangement of their circulating organs, it is immediately mixed up with the blood. This transudation has indeed been actually witnessed by Ramdohr and Rengger*, and even analysed by the last-mentioned physiologist, who found it to consist almost entirely of albumen.

(843.) The *respiratory organs* of the Insecta, as well as their *circulatory apparatus*, are constructed upon peculiar principles, and are evidently in relation with the capability of flying which distinguishes these minute yet exquisitely-constructed articulated animals. Any localized instruments for breathing, whether assuming the shape of branchiæ or lungs, would materially have added to the weight of the body, and moreover have rendered necessary an elaborate apparatus of arteries and veins for conveying the blood to and fro for the purpose of purifying it by securing its exposure to the influence of air. By the plan adopted, however, all these organs are dispensed with; and the organs of respiration, so far from increasing the weight of the animal, actually diminish its specific gravity to the greatest possible extent. The blood, in fact, in insects is not brought to any given spot to be exposed to oxygen; but the air is conveyed through every part of the system by innumerable tubes provided for that purpose; and thus all the complicated parts usually required to form a vascular system are rendered unnecessary. These observations, however, only apply to the insect in its perfect state; for in the larva and pupa conditions, where flight is not possible, various additional organs, frequently of considerable bulk, are provided, that we shall speak of in another place. If we examine the external skeleton of any large insect (a beetle, for example), we shall find, between the individual segments of the body, minute apertures or pores (*spiracles*) through which the air is freely admitted:

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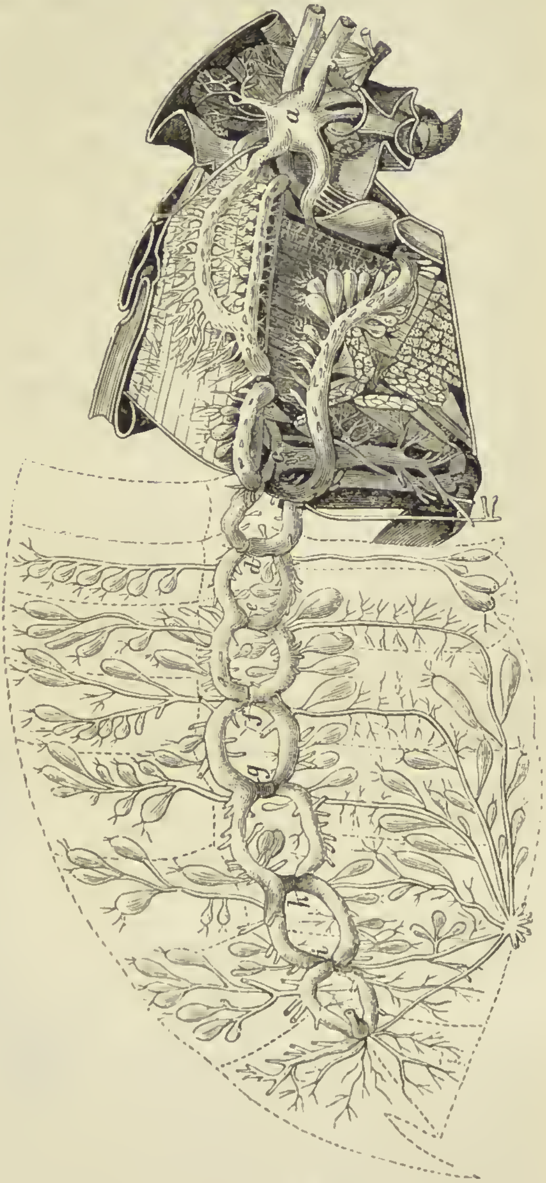
* Physiologische Untersuchungen über die thierische Haushaltung der Insekten. 8vo. 1817.

these openings, ten in number on each side of the body, are situated in the soft membrane interposed between the different rings, and not in the rings themselves,—a provision for the purpose of allowing their orifices to be opened or closed at pleasure, instead of being rigid and motionless. The margin of the spiracle is frequently encompassed by thick horny lips, which may be approximated by muscles provided for the purpose, so that the opening can be shut at pleasure, in order to exclude any extraneous substances that might otherwise obtain admission. In many insects, indeed, especially in beetles which crawl upon the dusty ground, an additional provision is necessary to prevent the entrance of foreign matter; and in such cases the spiracles are seen to be covered with a dense investment of minute and stiff hairs, so disposed as to form a sieve of exquisite fineness,—a beautiful contrivance by which the air is filtered, as it were, before it is allowed to pass into the breathing-tubes, and thus freed from all prejudicial particles. From every spiracle is derived a set of extremely delicate tubes (*tracheæ*), that pass internally, and become divided and subdivided to an indefinite extent, penetrating to every part of the body, and ramifying through all the viscera; so that air is thus supplied to the entire system. Upon more minutely inspecting these air-tubes, they are found to assume various forms in different parts of the body,—being sometimes simple

Fig. 161.

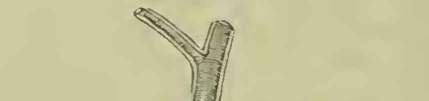


Respiratory apparatus of *Melolontha vulgaris.*

tubes of exquisite delicacy; in other cases they present a beaded or vesicular structure; and in many insects they are dilated at intervals into capacious cells or receptacles, wherein air is retained in great abundance. The beautiful figure given in the preceding page (fig. 161), taken from Straus-Durckheim's elaborate work upon the anatomy of the Cockchafer, will illustrate this arrangement. The spiracles, situated at the points respectively marked by the letters *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, open into two wide air-trunks, disposed longitudinally along the whole length of the body: from these, innumerable secondary branches are given off, many of them being seen to dilate into oval vesicles, from which smaller tracheæ proceed; while others, without any vesicular enlargement, plunge at once into different textures, and supply the viscera and internal organs. The muscular system, the legs, the wings, the alimentary canal, and even the brain itself, are permeated in all directions by these air-conducting tubes; and thus the oxygen penetrates to every corner of the body.

(844.) There is one circumstance connected with the tracheæ which is specially deserving of admiration, whether we consider the obvious design of the contrivance, or the remarkable beauty of the structure employed. It is evident that the sides of canals so slender and delicate as the tracheæ of insects would inevitably collapse and fall together, so as to obstruct the passage of the air they are destined to convey; and the only plan which would seem calculated to obviate this would appear to be, to make their walls stiff and inflexible. Inflexibility and stiffness, however, would never do in this case, where the vessels in question have to be distributed in countless ramifications through so many soft and distensible viscera; and the problem therefore is, how to maintain them permanently open, in spite of external pressure, and still preserve the perfect pliancy and softness of their walls. The mode in which this is effected is as follows:—Between the two thin layers of which each air-vessel consists, an elastic spiral thread is interposed (fig. 162, *a*), so as to form by its revolutions a firm cylinder of sufficient strength to ensure the calibre of the vessel from being diminished, but not at all

Fig. 162.



Tracheal tube of an insect, highly magnified, showing, at *a*, the elastic spiral thread.

interfering with its flexibility, or obstructing its movements; and this fibre, delicate as it is, may be traced, with the microscope, even through the utmost ramifications of the tracheæ,—a charactor whereby these tubes may be readily distinguished.

(845.) There is a limit, observes Dr. Williams*, different in different structures, at which the spiral thread ceases; and at this point the *membranous trachea* begins. It is not the external covering which ceases, but the spiral which, growing less and less visible, graduates insensibly into a continuous tube. The diameter of the "spiral" trachea constantly decreases as it divides; that of the membranous observes, throughout its entire course, whether it multiply into a network, or wavy brushes, or into the muriform plexus which exists in the substance of muscles, a uniformity which can compare only with that of the true blood-capillaries of the vertebrate animal. The tracheæ terminate differently, and form different plexuses, in different organs, according to the varying mechanical arrangements of the ultimate parts of the latter. They are evidently air-tubes throughout, even to their final extremes.

(846.) The primary, secondary, and tertiary air-tubes divide and subdivide arborescently, the branches never uniting, but the ultimate ramifications dividing and subdividing in tho same profuse retiform manner as the blood-capillaries of the vertebrate animal, supplying the muscles, the glands, the mucous membranes, the brain, and every other viscus. The large air-tubes which travel along the axes of the spacious blood-channels detach from their sides here and there minute wavy branches which float in the fluid, and appear to be expressly intended to aërate the fluids.

(847.) In all the transparent structures of insects, such as the wings, antennæ, branchiæ, &c., the blood-currents travel in the same passages as the tracheæ. On closer scrutiny it will be seen that a channel, such as that of the nervure of the wings, bearing in its centre a large tracheal tube, exhibits on one side a current going in one direction; on the other, another bearing in an opposite course. These are afferent and efferent, arterial and venous blood-streams. They aro bounded by separate walls. The afferent current is circumscribed by its own proper coats, the efferent by *its* own; and the trachea is placed intermediately, having parietes quite distinct from, although contiguous with, those of the blood-channels. This coincidence between the tracheæ and the blood-currents can be traced in the wings nowhere beyond the limits of the nervures into the scaly spaces that they circumscribe. The returning of the corpuscles at a certain point renders this fact quite unquestionable. Beyond this limit, only *the fluid elements*, not the corpuscles of the blood, penetrate. In this extra-vascular region it is cyclosis, not circulation, which governs the movements of the nutritive fluid. If, says Dr. Williams, everywhere the blood and the air travelled together, the inference would be that the sole design of the tracheal apparatus of the insect consisted in aërating the fluids. Since, however, the blood returns much before the tracheæ reach their remote penetralia, it is evident that the tracheal system in the insect fulfils some other function. What can be the meaning of those incomparable pneumatic plexuses—veritable *retia mirabilia*—which embrace immediately the very ultimate elements of the *solid* organs of the body? those microscopic air-tubes, which carry oxygen *in its gaseous form*, unfluidified by any intervening liquid, to the very seats of the fixed solids which constitute the fabric of the organism? The intense electrical and chemical effects developed by the immediate presence of oxygen at the actual scene of all the nutritive operations of the body, fluid and solid, give to the insect its vivid and brilliant life, its matchless nervous activity, its extreme muscularity, its voluntary power to augment the animal heat. Such contrivance, subtle and unexampled, reconciles the paradox of a being, microscopic in corporeal dimensions and remarkable for the relative minuteness of the *bulk* of its blood, sustaining a frame graceful in its littleness, yet capable of prodigious mechanical results.

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* *Loc. cit.*

(848.) We must now consider the mechanism by which air is perpetually drawn into the body of the insect, and again expelled. If the abdomen of a living insect be carefully watched, it will be found continually performing movements of expansion and contraction that succeed each other at regular intervals, varying in frequency, in different species, from twenty to fifty or sixty in a minute*, but occurring more rapidly when the insect is in a state of activity than when at rest. At each expansion of the abdomen, therefore, air is sucked in through all the spiracles, and rushes to every part of body; but when the abdomen contracts, it is forcibly expelled through the same openings. Burmeister even supposes that the humming noises produced by many insects during their flight must be referred to the vibration caused by the air streaming rapidly in and out of the spiracular orifices. Insects which live in water are obliged, at short intervals, to come to the surface to breathe, at which time they take in a sufficient quantity of air to last them during the period of their immersion; but if the spiracles are closed by any accident, or by the simple application of any greasy fluid to the exterior of their body, speedy death, produced by suffocation, is the inevitable result.

(849.) A moment's reflection upon the facts above stated concerning the respiration of insects will suggest other interesting views connected with the physiology of these little creatures. It is evident, in the first place, that their blood is all arterial; they can have no occasion for veins, as they have no venous blood, the whole of the circulating fluid being continually oxygenized as its principles become deteriorated. The perfection of their muscular power, their great strength and indomitable

* Sorg, Disquisitiones Physiologicæ circa Respirationem Insectorum et Vermium.

activity, are likewise intimately related to the completeness of their respiration; so that the vital energies of the muscular system are developed to the utmost, endowing them with that vigorous flight and strength of limb which we have already seen them to possess. It must likewise become apparent that, as the blood is freely exposed to the influence of oxygen in every portion of the insect to which the air-tubes reach, one great necessity for the existence of a circulatory apparatus is entirely done away with, and, as we have observed before, all those parts of the vascular system required in other animals for the propulsion of the vitiated blood through pulmonary or branchial organs are no longer requisite ; so that, by dispensing with the complicated structures usually provided for this purpose, the body is considerably lightened. The circulation of the nutritive fluids is, in fact, limited to their free diffusion amongst all the internal viscera, and is effected in the following manner: —If we examine the back of a silkworm, or of any transparent larva, a long pulsating tube is seen running beneath the skin of the back, from one end of the body to the other. Its contractions may readily be watched: they are found to begin at the posterior extremity, and are gradually continued forwards; so that the vessel presents a continual undulatory movement, by which the fluid contained in its interior is pushed from the tail towards the head. This dorsal vessel, which may be so well observed in the thin-skinned larva, exists likewise in the perfect insect, although, from the opacity of the integument, its movement is no longer apparent except by the vivisection of the animal.

(850.) This dorsal vessel, or heart as we shall call it for the sake of brevity, is organized in a very singular manner; for, instead of being a closed viscus, it communicates most freely, through several wide lateral apertures, with the cavity of the abdomen, and from thence derives the blood with which it is filled. The dorsal vessel is widest in the abdominal region; but is continued, nevertheless, through the thorax into the head, where it terminates as a simple or furcate tube—that is, not closed, but open at the extremity.

(851.) The structure of this remarkable heart has been fully investigated by Straus-Durckheim*, and is extremely curious: it consists, in the Cockchafer, of eight distinct compartments, separated from each other by as many valves formed by productions from the lining membrane, and so disposed that the blood passes freely from the hinder chambers into those which are placed more anteriorly, but is prevented from returning in the opposite direction.

(852.) Each compartment of the dorsal vessel communicates by two wide slits, likewise guarded by valves, with the cavity of the belly; so that fluids derived from thence will readily pass into the different chambers, but cannot again escape through the same channel. The arrangement of these valves will, however, be best understood by reference to the accompanying figure (fig. 163), representing a magnified view of the interior of a portion of the heart of the Cockchafer, as depicted by the celebrated entomotomist before alluded to. The organ has been divided longitudinally, so that one-half only is represented in the figure, upon a very large scale. The compartments (*a a a*) are distinctly composed of circular muscular fibres; the large valves (*d d*) separate the individual chambers, allowing the blood to pass in one direction only, viz. towards the head; while the openings (*c*), likewise closed by semilunar membranous valves, admit blood from the cavity of the abdomen, but effectually prevent its return.

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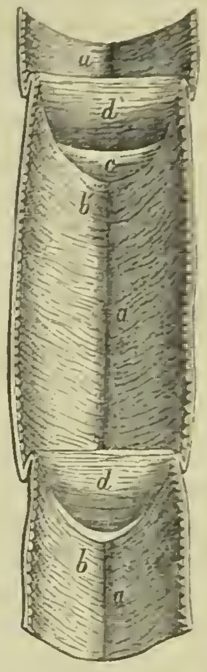
* *Op. cit.*

Fig. 163.



Internal view of a portion of the dorsal vessel of a Cockchafer: *a a a*, *b b*, muscular walls of the compartments; *d d*, intercompartmental valves; *c*, valve defending one of the orifices communicating with the general cavity of the abdomen.

(853.) Let us now consider the movements of the circulating fluids produced by the contractions of this apparatus. The chyle or nutritive material extracted by the food exudes, as we have already seen, by a species of percolation, through the walls of the intestine, and escapes into the cavity of the abdomen, where it is mixed up with the mass of the blood, which is not contained in any system of vessels, but bathes the surface of the viscera immersed in it. When any compartment of the heart relaxes, the blood rushes into it from the abdomen through the lateral valvular apertures; and as it cannot return through that opening on account of the valves (*c*) that guard the entrance, nor escape into the posterior divisions of the heart by reason of the valves (*d*), the contraction of the dorsal vessel necessarily forces it on towards the head. When it arrives there, it of course issues from the perforated termination of the heart, but does not appear to be received by any vessels, and therefore becomes again diffused through the body. The diffused character of the circulation met with in insects may easily be made a matter of observation in many of the transparent aquatic larvæ that are readily to be met with. When any of the limbs of these larvæ are examined under a powerful microscope, continual currents of minute oat-shaped globules are everywhere distinguishable, moving slowly in little streams—some passing in one direction, others in the opposite: but that these streams are not contained in vascular canals is quite obvious from the continual changes which occur in the course of the globules; their movements, indeed, rather resemble those of the sap in *Chara*, and other transparent vegetables, in which the circulation of that fluid is visible under a microscope.

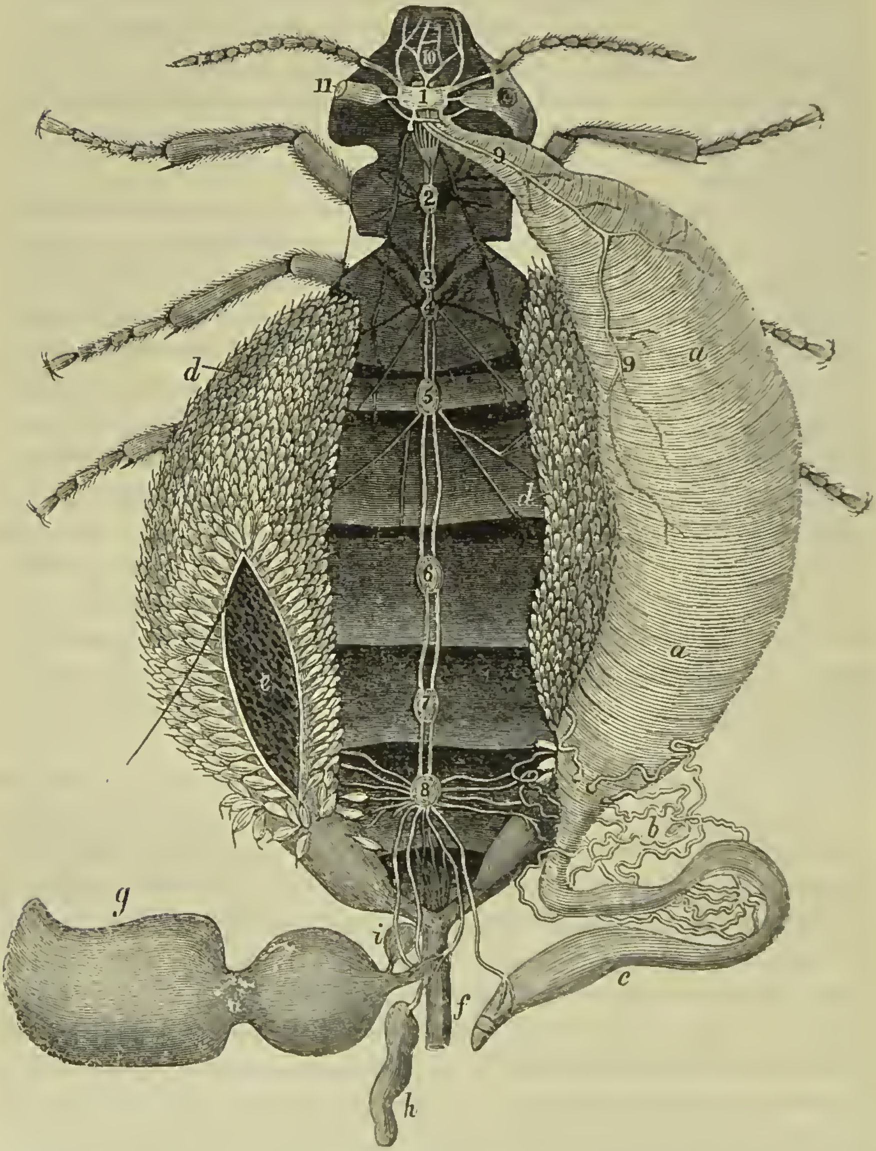
(854.) The organs appropriated to furnish the different secretions met with in the economy of insects are modified in their structure to correspond with the character of the circulation, and are invariably simple tubes or vesicles of various forms immersed in the fluids of the body, from which they separate their peculiar products. The poisonous saliva of bugs, and the innoxious salivary fluid of other insects—the bile and auxiliary secretions subservient to digestion—the venom which arms the sting of the wasp, and the silky envelope of the caterpillar,—are all derived from the same source, and in some mysterious manner elaborated from the blood by variously-formed vessels: but of this we have already given many examples, and others will present themselves in the following pages.

(855.) In the *nervous system* of the Insecta, we have many interesting illustrations of that gradual concentration of the parts composing it, and consequently of increased proportionate development of the nervous centres, corresponding with the more active movements and higher faculties by which the class before us is so remarkably distinguished from those forms of articulated animals that we have hitherto had an opportunity of examining. The supra-œsophageal ganglion, or brain, assumes a preponderance of size in relation to more perfect organs of sense and to instincts of more exalted character; the chain of ganglia placed along the floor of the abdomen is composed of a few large masses of sufficient power to animate the strong and energetic muscles of the limbs; and, moreover, anatomists have detected the existence of an additional nervous apparatus, apparently representing the sympathetic system of vertebrate animals, which is distributed to the viscera appropriated to digestion. Each of these divisions will therefore require a separate notice.

(856.) The brain, or encephalic ganglion (fig. 164, 1), is a nervous mass of considerable size placed above the gullet: it consists essentially of two ganglia united into one mass; and from it all the nerves appropriated to the special instruments of the senses are derived; so that it may naturally be regarded as the chief seat of sensation and intelligence. The nerves originating from this common sensorium are seen upon an enlarged scale in fig. 165: they are the *optic* (fig. 165, *a*), supplying the eyes, and the *antennal* (fig. 165, *e*), which run to the special instruments of touch, or *antennæ*—organs of a very singular character, that we shall examine more minutely hereafter. Two other cords of variable length (fig. 165, *g g*) are given off from the inferior aspect of the brain, and serve to connect it with the anterior ganglion of the ventral chain (fig. 165, *h*), to which some writers have thought proper to give the name of *cerebellum*, though upon what grounds it is difficult to conjecture: the mass last mentioned gives off various nerves to supply the parts connected with the *mandibles*, *maxillæ*, and other organs of the mouth.

(857.) The rest of the ventral chain of ganglia forms a continuous series (fig. 164, 2, 3, 4, 5, 6, 7, 8) of nervous centres arranged in pairs and united to each other by double cords of communication; but they vary much in number and relative magnitude in different families. Those situated in the thorax are usually of the greatest proportionate size, inasmuch as they furnish the nerves that supply the muscles of the wings and legs; the succeeding ganglia give branches to the abdominal segments; and the last, which is commonly of considerable bulk, supplies the sexual organs and the extremity of the colon.

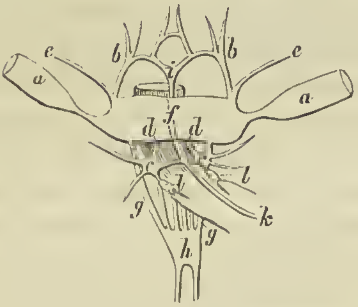
Fig. 164.



Anatomy of *Meloë*: *a*, the stomach; *b*, hepatic vessels; *c*, intestine; *d d*, ovaria; *e*, section of ovary showing the internal cavity; *f*, vagina; *g*, spermatheca; *h*, *i*, gluten-secretors: 1, supra-œsophageal ganglion of the nervous system; 2, 3, 4, 5, 6, 7, 8, ventral ganglia; 9 9, nervus vagus; 10, cephalic nerves; 11, optic ganglion.

(858.) It is the general opinion of modern physiologists, that the intimate composition of the nervous apparatus described above is by no means so simple as it appears to ordinary observation; and, since the experiments of Sir Charles Bell and Magendie demonstrated the existence of distinct columns or tracts in the spinal axis of vertebrate animals, various anatomists have endeavoured to show that corresponding parts may be pointed out in the ventral chain of articulated animals. There can, indeed, be no doubt that this portion of the nervous system of an insect corresponds in function with the medulla spinalis; and if, in the one case, the nerves which preside over the general muscular movements arise from a different column to that whence the nerves that correspond with the periphery of the body originate, while those which regulate the motions of respiration emanate from a distinct tract, we might reasonably suppose a similar arrangement to exist in the structure of the nervous system we are now examining. It has, in fact, been well ascertained that the nerves given off to the muscular system of the Homogangliata are not derived from the ganglionic masses themselves, but from the cords which connect them together, while the nerves distributed to the integument and external parts of the body communicate immediately with the ganglia. These different modes of origin give presumptive evidence that at least two distinct tracts exist in the central axis of insects; but, from the extreme minuteness of the different parts, it is not easy satisfactorily to demonstrate them separately. In the larger Articulata, however, as for example in the Crustaceans, two distinct columns of nervous matter are readily detected; it will therefore be more convenient to defer the investigation of this interesting subject until we have an opportunity of describing these parts upon an enlarged scale; enough has been said at present to enable the reader to compare the nervous axis of an insect with that of a lobster, and draw correct conclusions from the comparison.

Fig. 165.



Nervus vagus and sympathetic system of an Insect: *a a*, optic nerves; *d d*, supra-œsophageal ganglion; *l*, œsophagus; *b b*, origins of the recurrent nerve *i f k*; *g g*, nerves surrounding the œsophagus, and communicating between the supra-œsophageal ganglion, *d d*, and the first pair of ventral ganglia, *h*; *c c*, *l l*, sympathetic ganglia.

(859.) The last division of the nervous apparatus, which we have already mentioned as being the representative of the sympathetic system, consists of two portions,—one corresponding, in distribution at least, with the *nervus vagus* of Vertebrata, while the other represents, apparently, the *sympathetic ganglia*. The *nervus vagus*, as we shall call it, and which has been named by Swammerdam * and Cuvier the *recurrent*

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* Biblia Naturæ.

nerve, arises (fig. 165, *b b*) by two roots from the opposite extremities of the brain, close to the origins of the antennal nerves. The nervous cords thus derived soon unite to form a minute central ganglion (fig. 165, *i*), from which proceeds a single nerve (fig. 165, *f k*) that runs with the gullet beneath the brain, and spreads in delicate ramifications upon the œsophagus as far as the muscular stomach (fig. 164, 9 9), or to the gizzard when that organ exists.

(860.) The sympathetic system properly so called consists of four small ganglia (fig. 165, *c c*, *l l*), the two anterior of which communicate with the brain and with each other by means of connecting filaments. These ganglia are closely applied to the commencement of the œsophagus, and supply it with minute nerves.

(861.) Various are the conjectures entertained by different authors concerning the senses possessed by the members of the insect world, and the organs subservient thereunto. The possession of certain sources of perception has been alternately granted and denied; the nature of their sensations has been a fruitful subject of inquiry; and some physiologists have even gone so far as to deny the correspondence of the impressions derived by insects through the medium of their senses with those which we ourselves receive. It would lead us far out of our course did we even advert to the multiplicity of opinions and conjectures promulgated from various sources relative to these inquiries, and, perhaps, with little addition to our real knowledge. It is true that we cannot deny the possibility of the existence of other modes of sensation than those familiar to us; but it is likewise evident that, as we can never have the most remote conceptions concerning their nature, speculations respecting them are not at all calculated to lead to satisfactory conclusions. We must from necessity take our own senses as the standard of comparison, limiting our inquiries to examining how far insects possess means of intercourse with the external world similar to those which we enjoy, and, when we find certain faculties to exist, investigating the structure of the organs by which they are exercised.

(862.) The sense of *touch* is indubitably bestowed upon all insects: and, to judge from the perfection of the edifices which they build, and the precision of their usual operations, this must be extremely delicate. It is sufficient, however, to look at the external construction of the skeletons of Articulata to perceive that the hard and insensible integument spread over the entire surface of their bodies is but little calculated to receive tactile impressions. The antennæ, or feelers as they are popularly called, have been very generally regarded as being peculiarly instruments of touch; and whoever watches the proceedings of an insect in which these appendages are largely developed will, we apprehend, easily convince himself that they are employed to investigate surrounding objects by contact. Straus-Durckheim regards the feet as being specially appropriated to the sense of feeling: but this opinion seems quite inadmissible. Burmeister places the exercise of touch exclusively in the palpi attached to the maxillæ and labium, and observes that, in the larger insects, such as the predatory Beetles, the Grasshoppers, Humble-bees, and many others, the apex of the palpus is dilated into a white transparent and distended bladder, which, after the death of the insect, dries up and is no longer visible. This bladder he looks upon as the true seat of the sense in question, and remarks that the main nerve of the maxillæ and of the tongue spreads to it, and distributes itself upon its superior surface in minute ramifications.

(863.) Whether *taste* exists in insects as a distinct sense may admit of dispute: the tongue, already described, seems but little adapted to appreciate savours; and, seeing this, it is obvious that all opinions assigning the function of tasting to other parts are purely conjectural.

(864.) Many insects are certainly capable of perceiving odours; of this we have continual proof in the Flesh-fly and other species, that are evidently guided to their food, or select the position in which to deposit their eggs, by smell; but where the olfactory apparatus is lodged is still a matter of doubt. The *antennæ* and the *palpi* have each had the power of smelling assigned to them, but without much plausibility. The respiratory stigmata have been pointed out as performing the office of examining the air admitted for the purpose of breathing; yet other authors, with equal probability, look upon the ultimate ramifications of the tracheæ as forming one extensive nose. The interior of the mouth has been indicated by Treviranus*; while Kirby and Spence find, in the Necrophori and other insects remarkable for acuteness of smell, an organ in close connexion with the mouth, to which they attribute the perception of odoriferous particles: this is a cavity situated in the upper lip, containing a pair of circular pulpy cushions covered by a membrane transversely striated or gathered into delicate folds.

(865.) We are scarcely better informed concerning the organs of *hearing*; but that insects are capable of perceiving sounds is proved by the fact of many tribes being capable of producing audible noises, by which they communicate. There seems, indeed, to be little doubt that the auditory apparatus is in some way or other connected with the antennæ. Some have supposed that these slender and jointed organs, supplied, as they are, with large nerves, are themselves capable of appreciating sonorous vibrations. Burmeister† thinks that, as in crabs and lobsters, it is at the base of the antenna that the ear is situated, and observes that if we examine the insertion of these appendages, we shall detect there a soft articulating membrane, which lies exposed, and is rendered tense by the movements of the antenna: this he looks upon as representing the drum of the ear, and conceives that it is so placed as to receive impressions of sound, increased by the vibratory movements communicated to the antennæ by the sonorous undulations of the atmosphere.

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* Vermischte Schriften, vol. ii.

† *Op. cit.* p. 296.

(866.) In some moths, Treviranus[*] has discovered structures which would seem to be indubitably real auditory organs. He found in front of the base of each antenna a thin membranous drum, behind which, large nerves, derived from those supplied to the antennæ, spread themselves out; but this apparatus has not been detected in other insects.

(867.) The eyes of insects are of two kinds, simple and compound,—the former being insulated visual specks; while the latter consist of agglomerations of numerous distinct eyes, united so as to form most elaborate and complex instruments of sight.

(868.) Some insects, as the Dictyotoptera and Thysanoura, only possess simple eyes; others, as for example the Coleoptera, have only compound eyes; but in general both kinds exist together. In the *Sirex gigas* (fig. 171), for instance, besides the large hemispherical organs of sight, situated at the sides of the head, three simple spots are seen upon the vertex, which are likewise appropriated to vision.

(869.) The structure of the eyes has been most minutely investigated by several distinguished entomotomists; and the labours of Marcel de Serres[†], Joh. Müller[‡], Straus-Durckheim[§], and Dugès[||] have done much to dispel the mistaken notions entertained by preceding anatomists.

(870.) The *simple eyes* consist of a minute, smooth, convex, transparent cornea, in close contact with which is a small globular lens; behind this lens is placed the representative of the vitreous humour, upon which a nervous filament spreads out, so as to form a retina: the whole is enclosed in a layer of brown, red, or black pigment, which, bending round the anterior surface of the eye, forms a distinct coloured iris and pupillary aperture. Such an arrangement evidently resembles what is met with in higher animals, and is remarkable for its simplicity: but it is far otherwise with the compound eyes of insects; for these are constructed upon principles so elaborate and complex, that we feel little surprise at the amazement expressed by early writers who examined them, although their ideas concerning their real structure came far short of the truth.

(871.) The *compound eyes* of insects are two in number, situated on the lateral aspects of the head, the form of each being more or less hemispherical. When examined with a microscope, their surface is seen to be divided into a multitude of hexagonal facets, between which minute hairs are generally conspicuous. The number of facets or corneæ (for such, in fact, they are) varies in different genera: thus, in the Ant (*Formica*) there are 50; in the common House-fly (*Musca domestica*), 4000; in some Dragon-flies (*Libellula*), upwards of 12,000. In Butterflies (*Papilio*) 17,355 have been counted; and some Coleoptera (*Mordella*) possess the astonishing number of 25,088 distinct corneæ.

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[*] Annalen der Wetterau. Gesel. f. d. ges. Naturk. vol. i. 1809.

[†] Mém. sur les Yeux composés et les Yeux lisses des Insectes. Montpellier, 8vo, 1813.

[‡] Zur vergleichenden Physiologie des Gesichtssinnes. 8vo, 1826.

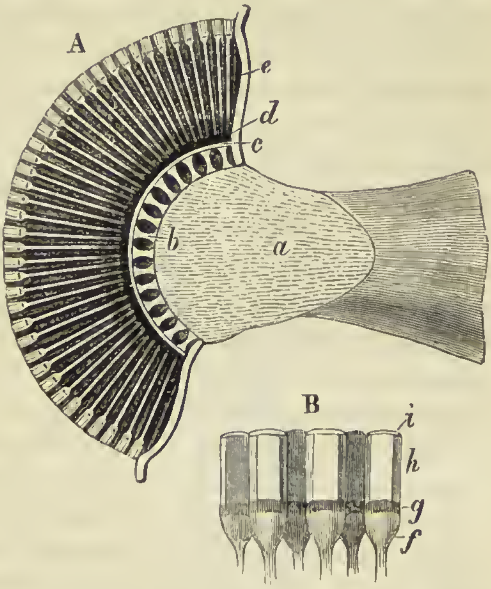
[§] Ann. des Sci. Nat. tom. xviii.

[||] Ibid. tom. xx.

(872.) But in order to appreciate the wonderful organization of these remarkable organs of sight, it is necessary to examine their internal structure: every cornea is then found to belong to a distinct eye, provided with a perfect nervous apparatus, and exhibiting its peculiar lens, iris, and pupil; thus being completely entitled to be considered a distinct instrument of vision.

(873.) By attentively examining the annexed figure, representing a section of the eye of the Cockchafer (*Melolontha*), as displayed by Straus-Durckheim, the whole structure of the organ will be readily understood. The optic nerve (fig. 166, *a*), derived immediately from the supra-œsophageal mass of nervous matter, swells soon after its origin into a rounded ganglion nearly half as large as the brain itself. From the periphery of the ganglion so formed arise a considerable number of secondary nerves (*b*), which are very short, and soon come in contact with a layer of pigment (*d*), that in the Cockchafer is of a brilliant red colour, and is placed concentrically with the convex outer surface of the eye. Behind this membrane (called by Straus-Durckheim the *common* choroid), the secondary optic nerves (*b*) unite to form a membranous expansion of nervous matter (*c*), which may be denominated the *general retina*. From the nervous expansion so formed arise the proper optic nerves (*e*), appropriated to the individual eyes, or *ocelli*, as we shall term them. These nervous filaments are as numerous as the facets of the cornea, and traverse the common choroid to radiate towards the individual eyes whereunto they are respectively destined, and the structure of which we must now proceed to examine. In fig. 166, B, a portion of the circumference of the compound eye is represented upon

Fig. 166.



Structure of the eye of a Cockchafer. A, sectional view: *a*, optic ganglion; *b*, secondary nerves; *c*, general retina, in front of which is a layer of pigment, *d*; *e*, proper optic nerves, supplying the individual facets of the compound eye. B, a group of ocelli, much magnified: *f*, bulb of optic nerve; *g*, layer of pigment; *h*, vitreous humour; *i*, cornea.

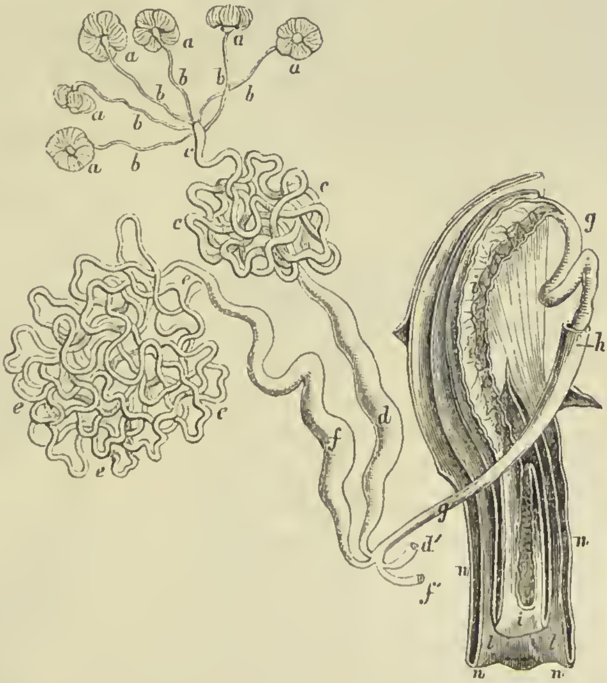
a very large scale, in order to show the construction of the hexagonal ocelli that enter into its composition. Each cornea (*i*) is a double convex lens, adapted by its shape to bring to a focus the rays passing through it. Behind every lens so constituted is placed a hexahedral transparent prism (*h*), which from its office may be compared to the vitreous humour of the human eye; and it is upon the posterior extremity of these prisms that the proper optic nerves (fig. 166, A, *e*) spread themselves out, so as to form so many distinct retinæ. When we reflect upon the extreme minuteness of the parts above alluded to, we may well expect slight discrepancies to occur between the accounts given of them by different anatomists. Straus-Durckheim represents every optic nerve as terminating in a minute pyriform bulb (fig. 166, B, *f*), and points out a dark layer of pigment (*g*), which forms a choroid tunic proper to each ocellus; while, according to Müller and Dugès, the vitreous humours (*h*) are conical, and terminate posteriorly in a sharp point, upon which the terminal expansion of the optic nerve spreads out, without any pyriform enlargement; they likewise deny the existence of the proper choroid (*g*) in the situation indicated by Straus-Durckheim, but find a black pigment situated immediately behind the cornea, that at first sight would appear to be continuous over the whole surface of the eye. Even Cuvier seems at one time to have adopted this opinion. Müller, however, found that, upon carefully removing the internal structures of the organ, leaving the pigment untouched, the dark varnish in question, although very thick at the lines of union of the different facets, where it is continuous with a choroid that separates the individual ocelli, yet towards the centre of each facet becomes exceedingly thin, and at the very centre is quite wanting, so that a minute perforation or pupil is thus left, through which the rays of light enter. The existence of the secondary optic nerves (*b*) and common retina (*c*) is likewise disputed by Müller and Dugès, who consider the proper optic nerves to arise immediately from the surface of the brain.

(874.) With regard to the wonderfully complex structure of these organs, Straus-Durckheim suggests that, the eyes of insects being fixed, nature has made up for their want of mobility by their number, and by turning them in all directions; so that it might be said that these little animals have a distinct eye for every object. But here we are naturally tempted to inquire whether insects see at the same time distinctly with every one of these eyes, or if they distinguish with one eye only. Upon this point Straus-Durckheim observes that, if they saw clearly with all, the great number of images would necessarily produce confusion, and would prevent creatures so organized from paying special attention to any determinate point. It is probable, therefore, that one ocellus only is at any given time placed in circumstances precisely adapted to the complete examination of an object, the animal seeing things imperfectly with the rest, in the same manner as we see objects situated nearer to us or further off than that upon which we fix our attention; so that, according to this supposition, insects would see very distinctly with one eye only, exactly as we see confusedly an extensive landscape, although we only distinguish a small part of it.

(875.) In all insects the sexes are quite distinct; and the generative apparatus, both of the male and female, consists of various secreting organs with their excretory ducts: in the male, such glands furnish the impregnating secretions; and in the female give origin to the ova, and provide the covering wherein the eggs are enveloped.

(876.) Commencing with a description of the male organs, we find in the Cockchafer various parts represented in the accompanying figure, taken from the admirable work of Straus-Durckheim already so often quoted. The testicles of *Melolontha* (fig. 167, *a a*) are six in number on each side of the body; but, in the engraving, those of one side only are delineated. Every testis consists of a vesicular organ, hollow internally, which, being immersed in the juices of the insect, separates therefrom the seminal fluid. Six ducts (*b b b*) may be called *vasa deferentia*, and convey the spermatic liquor into a common canal (*c c*), of very considerable length and much convoluted. Although slender at its commencement, this tube ultimately expands into a wider portion (*d*), wherein,

Fig. 167.



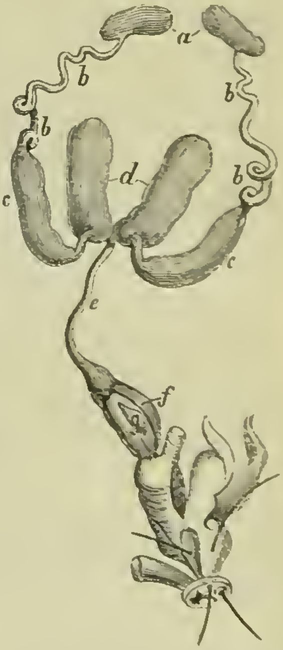
Male generative organs of *Melolontha vulgaris*: *a a a*, testicular glands; *b b b*, vasa deferentia; *c c*, common canal; *d*, its dilated portion; *d'*, termination of the corresponding canal from the opposite side; *e e f*, *f'*, auxiliary glands; *g g*, common duct enclosed in a sheath, *h*; *i i*, ejaculatory apparatus; *l l*, *n n*, section of penis.

no doubt, the semen accumulates, and which has been called by authors the *vesica seminalis*.

(877.) The canal (*d*) terminates by joining the corresponding duct from the opposite side (*d'*) to form a common tube (*g*); but just at the point of junction they are joined by two long auxiliary vessels (*f*, *f*), that have been named *sperm-vessels, gluten-vessels,* and *gum-vessels* by different authors, but which appear to be appropriated to the production of some fluid, perhaps analogous to the prostatic fluid of mammalia, whereby the bulk of the seminal liquor is increased in order to facilitate its expulsion. Each of these auxiliary vessels consists of two parts—a long and much-convoluted portion (*e e e*), forming the secreting organ; and a dilatation (*f*), that must be looked upon as a reservoir for the fluid elaborated. The common canal (*g*) receives all these secretions: it is at first enclosed in a kind of sheath (*h*), but, soon becoming muscular, it dilates into a strong contractile canal (*g*, *i*), called the *ductus ejaculatorius*, which is continued to the extremity of the penis.

(878.) The intromittent organ itself is composed of two parts—a protrusible corneous tube (*l l*), and an external horny sheath (*n n*), in which the former is usually concealed and protected.

Fig. 168.

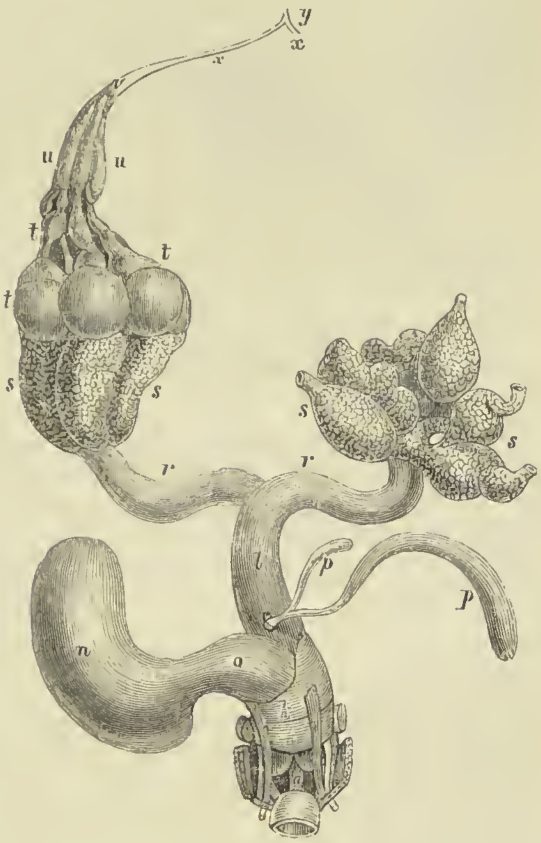


Male generative organs of the Hive Bee (*Apis mellifica*): *a*, testes; *b b*, vasa deferentia; *c c*, seminal receptacles; *d*, auxiliary glands; *e*, common excretory duct; *f*. *g*, ejaculatory sacculus.

(879.) Great variety, of course, is found in the number, form, and general arrangement of all the parts alluded to in the above description, when examined in different insects. In the Hive-bee, for example, the testes (fig. 168, *a*) are only two in number, and are simple oval vesicles; the *vasa deferentia* (*b b*) are short, and the *seminal receptacles* (*c*) form membranous sacculi. The auxiliary secreting organs (*d*), although placed in the same position as in *Melolontha*, are represented by capacious cæca; while the common excretory duct (*e*) swells into a strong and muscular bag (*f*), which constitutes the ejaculatory apparatus. Still, however, it is easy to see that, although diversified in appearance, the parts here found are essentially similar to those met with in the Cockchafer, and represent respectively the same organs.

(880.) The female apparatus of reproduction presents a general correspondence, both in form and arrangement, with the sexual parts of the male insect. The ovaria are simple secreting sacculi, or elongated tubes, in which the germs or ova are produced instead of the seminal liquor; and the excretory canals, or egg-passages, with the organs appended to them, although appropriated to different functions, strikingly resemble the organs met with in the other sex.

Fig. 169.



Female generative organs of the Cockchafer (*Melolontha vulgaris*): *s s*, *t t*, *u u*, ovigerous tubes; *y x*, their ligamentous origin; *r r*, excretory canals; *l*, common oviduct; *p p*, gluten-secretors; *n o*, spermatheca.

(881.) In the female of *Melolontha* the *ovaria* are long tubes, forming two distinct fasciculi symmetrically situated on the two sides of the body. At their commencement (fig. 169, *u u*) the ovigerous tubes are slender, and the ova which they contain at this point are in a very rudimentary state of development; they generally dilate, however (*t t t*); and as they expand, the ova are seen to attain larger dimensions. Near its termination, each ovarian tube assumes a granulated texture (*s s*); and they all ultimately open into the corresponding excretory canal (*r r*).

(882.) All the ovarian tubes of one side are united into a bundle, by a ligament (*y x*) which Joh. Müller * traced to the dorsal vessel, and believed to be a vascular canal adapted to bring blood immediately into the tubes wherein the ova are formed; but no satisfactory evidence has been adduced in proof of the existence of such an extraordinary communication, and the thread in question is most probably a mere ligamentous connexion.

(883.) Taking the higher animals as a standard of comparison, we may suppose the formation of the eggs in these tubes to be accomplished in the following manner:—In the upper part of the tube (*u*) is formed the yelk, enclosed in its peculiar membrane, and provided with that wonderful germ from which, after impregnation, the future being is to be developed; as the yelk slowly descends to the more dilated parts of the canal (*t t*), it becomes clothed with the albumen which constitutes the white of the egg, and ultimately, before quitting the nidus of its formation, receives from the granular termination of the ovary its last integument or shell. Thus completed, it passes into the excretory canal (*r r*); and this, meeting the corresponding tube derived from the ovaries of the opposite side, joins it to form the common oviduct (*l*), through which the egg is conducted out of the body.

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* Nova Acta Phys.-Med. Nat. Cur. vol. xii. pt. 2.

(884.) But we must now advert to certain appendages connected with the common oviduct. These are of two kinds, the *gluten-secretors* and the *spermatheca*.

(885.) The *gluten-secretors* (fig. 169, *p p*) are glandular cæca opening into the common egg-canal, and are apparently destined to furnish a glutinous fluid with which the eggs become invested before they are expelled from the body; and thus they are frequently united into long chains and variously-shaped masses, or else the adhesive varnish thus secreted serves to glue the ova to situations favourable to the development of the embryo.

(886.) The other organ, or *spermatheca* (fig. 169, *n o*), has a widely different office, being a receptacle provided to receive the seminal secretion of the male during copulation: it is always situated upon the upper aspect of the oviduct, into which it opens by a small orifice surrounded by a thickened margin or sphincter embracing the neck of the bag, and so disposed as either to retain the enclosed fluid, or to allow it to escape into the oviduct. That this organ really does receive and retain the seminal liquor is proved by the presence of seminal animalcules in its contents; but the matter has been placed beyond a doubt by the experiment of John Hunter*, who actually succeeded in fecundating the eggs of an unimpregnated female by applying to them a little of the fluid contained in its cavity: but that the reader may comprehend fully the reason of such an arrangement, it is necessary to consider the circumstances under which insects propagate.

(887.) In most animals, sexual union may be repeated several times during the life of individuals; but in insects intercourse between the sexes is permitted to take place once only; and this solitary congress must suffice for the impregnation of all the ova, however numerous, and however imperfect may be the development of some of them at the time when the embraco occurs.

(888.) Let us take the Hive-bee as an example: in the females of this insect the ovigerous tubes (fig. 170, *a a*) are excessively numerous, and the eggs produced in them may amount to between 20,000 and 30,000. These eggs, of course, arrive at maturity in succession, and not all at once; so that, at the moment when the queen-bee meets her selected mate, perhaps the majority of the ova are not in a sufficiently mature condition to be rendered fertile. Nevertheless the meeting of the sexes cannot be repeated; for no sooner has copulation taken place than the favoured male dies, and, by a simultaneous butchery, all the other males, or drones as they are commonly designated, are destroyed by the working inhabitants of the hive. The quantity of the fecundating liquor, therefore, supplied by one connexion must serve to fertilize all the eggs produced during the lifetime of the queen-bee; and for this purpose it is stored up in the spermatheca (fig. 170, *c*); so that, how numerous soever may be the eggs formed, they are all vivified as they pass out through the oviducts (*b*, *e*), and thus come in contact with the orifice of the reservoir of semen.

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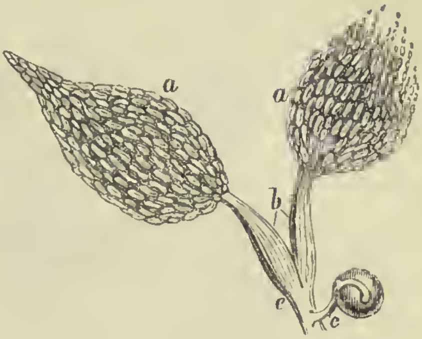
* Home's Lectures on Comp. Anat. vol. iii. p. 370.

Fig. 170.



Female generative organs of the Queen Bee: *a a*, ovigerous tubes; *b b*, oviducts; *c*, spermatheca; *e*, vagina, or common excretory duct.

(889.) In *Meloë variegatus* (fig. 164) the ovaria (*d*) consist of wide and capacious sacs, covered externally with innumerable glandiform vesicles, opening into the cavity of the ovary (*e*). The gluten-secretor (*h*) and the spermatheca (*g*) are seen, as in *Melolontha*, appended to the common oviduct (*f*); but the spermatheca has a small accessory vesicle (*i*) connected with it, not found in the former examples.

(890.) In many insects, especially of the Hymenopterous order, the generative apparatus is terminated externally by peculiar instruments provided for the purpose of introducing the eggs into a proper situation. This is particularly remarkable in the *Ichneumons*, which deposit their ova in living caterpillars; and in the Saw-flies (*Tenthredo*), whose eggs are insinuated into the substance of the leaves, or even of the branches of trees. To describe all the contrivances employed for this purpose would lead us far beyond our prescribed limits: one example of an organ of this description must suffice.

(891.) In *Sirex gigas* (fig. 171) the ovipositor consists apparently of three pieces of considerable length, seen in the figure to project from the inferior margin of the abdomen. Of these pieces, two form a sheath enclosing a third, called the *terebra*, or borer, which in the *Tenthredo* contains two saws of extremely beautiful construction, as we learn from an account of them given by Professor Peck, and quoted by Kirby and Spence*. The original description, which it would be unpardonable to abbreviate, is as follows. "This instrument," says Professor Peck, "is a very curious object; and, in order to describe it, it will be proper to compare it with the *tenon-saw* used by cabinet-makers, which, being made of a very thin plate of steel, is fitted with a back to prevent its bending: the back is a piece of iron, in which a narrow and deep groove is cut to receive the plate, which is fixed. The saw of the Tenthredo is also furnished with a back; but the groove is in the plate, and receives a prominent ridge of the back, which is not fixed (to the saw),

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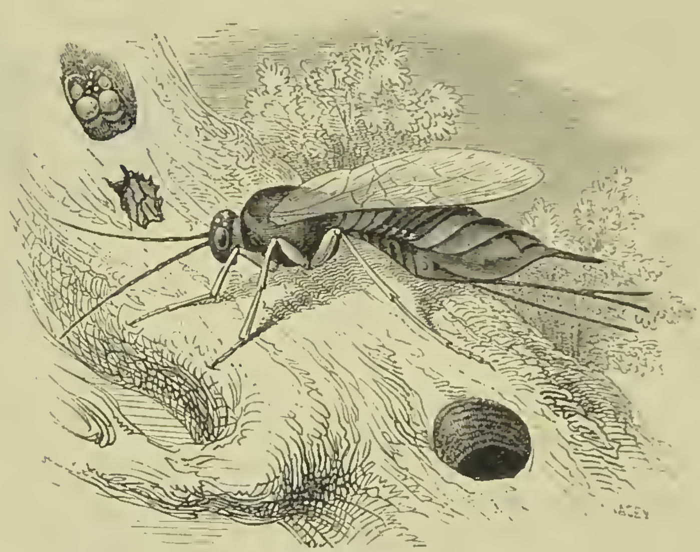
* Introd. to Entom. vol. iv. p. 161.

Fig. 171.



Sirex gigas.

but permits the saw to slide forward and backward as it is thrown out and retracted. The saw of artificers is single; but that of the Tenthredo is double, and consists of two distinct saws with their backs: the insect, in using them, first throws out one, and, while it is returning, pushes forward the other; this alternate motion is continued till the incision is effected, when the two saws, receding from each other, conduct the egg between them into its place."

(892.) With respect to the number of eggs laid by insects, it varies in different species: the Flea, for example, lays about twelve, and many Diptera and Coleoptera average perhaps fifty; but others are far more prolific: among moths, for example, the Silkworm produces 500, and some from 1000 to 2000; the Wasp (*Vespa vulgaris*) deposits 3000: the Ant (*Formica*), from 4000 to 5000. The Queen-bee is said by Burmeister to lay from 5000 to 6000; but Kirby and Spence consider that in one season the number may amount to 40,000 or 50,000, or more. Yet, surprising as this latter statement may appear, the fecundity of the Queen-bee is far inferior to that of the White Ant (*Termes fatalis*): for the female of this insect extrudes from her enormous matrix innumerable eggs at the rate of sixty in a minute, which gives 3600 in an hour, 86,400 in a day, and 2,419,200 in a lunar month. How long the process of oviposition continues in the termite is unknown; but if it were prolonged through the entire year, the amazing number of 211,449,600 eggs would proceed from one individual: setting, however, the number as low as possible, it will exceed that produced by any known animal in the creation.

(893.) The *Aphides*, or plant-lice, furnish a remarkable instance of fecundity. In these insects it has been satisfactorily ascertained, by Bonnet, Lyonet, and Reaumur, that a single sexual intercourse is sufficient to impregnate not only the female parent, but all her progeny down to the ninth generation! The original insect still continues to lay when the ninth family of her descendants is capable of reproduction; and Reamur estimated that, even at the fifth generation, a single Aphis might be the great-great-grandmother of 5,904,900,000 young ones.

(894.) The impregnated ova of the Aphis* are deposited at the close of summer, in the axils of the leaves either of the plant infested by the species, or of some neighbouring plant; and the ova, retaining their latent life through the winter, are hatched by the returning warmth of spring, giving birth to a wingless hexapod larva. This *larva*, if circumstances, such as warmth and food, be favourable, *will produce a brood (or indeed a succession of broods) of eight larvæ like itself, without any connexion with the male.* In fact, no winged females have, at this season, appeared. If the virgin progeny be also kept from any access to the male, each will again produce a brood of the same number of aphides; and careful experiments have shown that this procreation from a virgin mother will continue to the seventh, the ninth, or the eleventh generation, before the spermatic virtue of the ancestral coitus be exhausted. In the last larval brood, individual growth and development proceed further than in the parent, and some individuals become metamorphosed into winged males, others into oviparous females. By these the ova are developed, impregnated, and oviposited, and thus provision is made for disseminating the individuals, and for continuing the existence of the species over the severe famine-months of winter†.

(895.) This mode of reproduction is evidently referable to the nursing system of Steenstrup (§ 383); and inasmuch as, in the system of nursing, the whole advancement of the welfare of the young is effected only by a still and peaceful organic activity—is only a function of the vegetable life of the individual, so also all those forms of animals in whose development the nursing system obtains actually remind us of the propagation and vital cycle of plants. For it is peculiar to plants, and as it were their special characteristic, that the germ, the primordial individual in the vegetation or seed, is competent to produce individuals which are again capable of producing seeds or individuals of the primary form, or that to which the plant owed its origin, only by the intervention of a whole series of generations. It is certainly the great triumph of morphology that it is able to show how the plant or tree (that colony of individuals arranged in accordance with a simple vegetative principle or fundamental law) unfolds itself through a frequently long succession of generations into individuals becoming constantly more and more perfect, until, after the immediately precedent generation, it appears as *Calyx* and *Corolla*, with perfect male and female individuals, stamens (*Staubblätter*) and pistils (*Fruchtblätter*), and, after the fructification, brings forth seed which again goes through the same course.

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* Owen, Parthenogenesis, p. 24.

† "The multiplication of these little creatures is infinite and almost incredible. Providence has endued them with privileges promoting fecundity which no other insects possess: at one time of the year they are oviparous, at another, viviparous; and, what is most remarkable and unparalleled, the sexual intercourse of one original pair serves for all the generations which proceed from the female for a whole succeeding year. Reaumur has proved that in five generations one Aphis may be the progenitor of 5,904,900,000 descendants; and it is supposed that in one year there may be twenty generations." —Kirby and Spence, Introd. to Entom. vol. i. p. 175.

(896.) To facilitate the comparison thus instituted by Steenstrup, Professor Owen has devised the diagrams copied in the opposite figure, which place before the eye the whole of this most interesting subject*.

(897.) The pollen-tube or filament (fig. 172, 1, *a*) discharged from the pollen-cell (*a'*) in the plant, represents the spermatozoon (*a* 2 & 3) in the animal; its contents (whether by endosmose or perforation is immaterial) are received by the ovule (*b* 1), which is afterwards discharged and becomes free. Under favourable circumstances the formation of the embryo takes place with manifold modifications, but essentially by the multiplication of cells, according to a process which is as much entitled to be called continuous growth as that process in the formation of the Conferva. The embryo (*c*) proceeds to develope the radicle and the plumula (*d*) by the metamorphosis and coalescence of certain of the impregnated cells, retaining the major part, however, as cells; and thus the first individual plant or pair of individuals, as in Dicotyledons, is established.

(898.) The ovum (fig. 172, 2, *b*) of the zoophyte proceeds to develope its free locomotive embryo (*c*) by an analogous multiplication of cells, certain of which are metamorphosed into an external skin with vibratile cilia; the embryo settles, subsides, shoots out rays analogous to the radicle of the plant, but for attachment only, and grows afterwards as a stem, from which a polyp (*d*) is speedily developed, answering to the first cotyledonal leaf or leaves in the plant (fig. 172, 1, *d*). Both plant and zoophyte proceed to develope by gemmation, the one a succession of leaves (*e e*), the other of polyps (*e e*) associated by the continuous growth of the connecting parts; and finally the plant, by a metamorphosis of part of the stem and certain leaves, produces the flower or fructification (*f*, *g*, *h*, *i*); and the zoophyte, by a modification also of its stem and certain polyps, produces an "ovarian vesicle" (*f*), or a modified polyp (*g*), or a medusiform individual (*l*), which is set free: in both cases the end to be attained is the diffusion of the species by means of impregnated seeds or ova.

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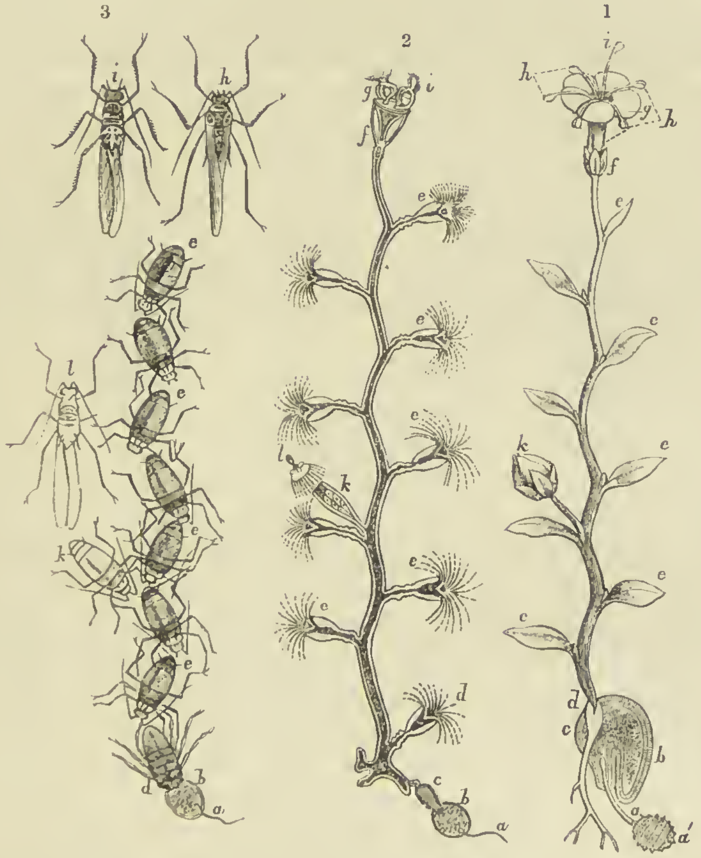
* *Vide* Owen, Parthenogenesis, p. 58 *et seq.*

(899.) Now if we compare fig. 172, 3, in which are represented the corresponding stages intervening between the ovum and the perfect male and female individuals of the Aphis, with fig. 172, 1 & 2, the analogy between these stages in the plant, the polyp, and the insect will be seen to be both true and close. The spermatozoon (*a*) of the male Aphis (*h*) answers to the pollen-filament (fig. 172, 1, *a*) of the male leaf or stamen (*h*). The ovum (*b*) of the female Aphis (*i*) answers to the ovule (*b*) of the female leaf or pistil (*i*); by their combination the impregnated ovum results. The same processes of cell-formation ensue, and the embryo Aphis (*d*) is formed by the combination and metamorphoses of certain of these secondary germ-cells; but it retains the rest as a germ-mass in its interior, which may be compared with the cells of the pith in the plant, and with the cells or nuclear granules in the corresponding more fluid part of the pith of the polyp. Under favourable circumstances of nutriment and warmth, certain portions of the retained germ-mass repeat the process of em-

Fig. 172.



Comparative view of the reproductive process in a Plant, a Campanularian zoophyte, and a female Aphis, the corresponding parts being indicated by similar letters, as explained in the text.

bryonic formation, and a larval individual (fig. 172, 3, *e*) like that from the ovum is thus produced, which is only not retained in connexion with its parent because the abdominal integument is not co-extended with it.

(900.) The generation of a larval Aphis may be repeated from seven to eleven times without any more accession to the primary spermatic virtue of the retained germ-masses than in the case of the zoophyte or plant: one might call the generation an "internal gemmation;" but this phrase would not explain the conditions essential to the process, unless we previously knew those conditions in regard to ordinary or external gemmation. At length, however, the last apterous or larval Aphis so developed proceeds to be metamorphosed, as it is termed, into a winged individual, in which, only, the fertilizing filaments are formed, as in the case of the stamens of the plant (*h*); another larval Aphis (fig. 172, 3, *i*) perfects the female generative organs, and developes the ovules, as in the case of the pistil (fig. 172, 1, *i*). We have, in fact, at length male (*h*) and female (*i*) individuals, preceded by reproductive individuals (*e e*) of a lower or arrested grade of organization, analogous to the gemmiparous polyps of the zoophytes (fig. 172, 2, *e e*) and the leaves (fig. 172, 1, *e e*) of the plant.

(901.) The process of development in the Aphides is, for its better intelligibility, described above by Professor Owen as one of a simple succession of single individuals, but it is much more marvellous in nature. The first-formed larva of early spring procreates not one but eight larvæ like itself in successive broods; and each of these larvæ repeats the process; and it may be again repeated in the same geometrical ratio, until a number which figures only can indicate, and which language almost fails to express, is the result. The Aphides, generated from virgin parents by this process of internal gemmation, are as countless as the leaves of a tree to which they are so closely analogous. The wingless larval Aphides are not very locomotive; they might have been attached to one another by continuity of integument, and each have been fixed to suck the juices from the part of the plant where it was brought forth. The stem of the rose might have been incrusted with a chain of such connected larvæ, as we see the stem of a fucus incrusted with a chain of connecting polyps, and only the last developed winged males and oviparous females might have been set free. The connecting medium might even have permitted a common current of nutriment, contributed to by each individual, to circulate through the whole compound body. But how little of anything essential to the animal would be affected by cutting through this hypothetical connecting and vascular integument, and setting each individual free!*

(902.) In all the great class of Insects, the blood is equably diffused through the visceral cavity, and is contained in the spaces intervening between the muscles, nerves, tegumentary organs, &c., and in the still smaller lacunæ that exist between the fibres or constituent lamellæ of the various organic tissues. The fluid thus diffused is characterized by the presence of globules or corpuscles of determinate shape; and in most cases it is easy to ascertain by means of the microscope that the circulation is carried on in a system of irregular cavities, much in the same way as the blood of vertebrate animals is in the vascular system with which they are furnished.

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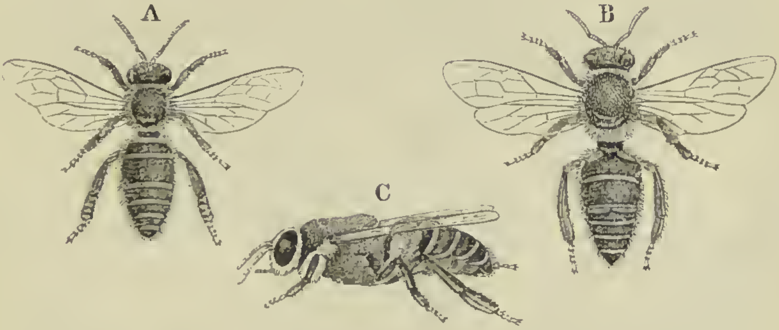
* *Loc. cit.* p. 61.

(903.) Innumerable are the means employed by nature to keep the balance between the increase and destruction of the insect tribes; and countless enemies are provided for the purpose of checking their inordinate accumulation.

Fig. 173.



The Hive Bee (*Apis mellifica*). A, Working Bee. B, fertile female, or Queen Bee. C, the male, or Drone.

(904.) Among the most remarkable provisions for preventing superabundant fertility is that law which compels the most prolific insects to live in large societies, and permits but one female out of a multitude to lay eggs. As an example of this, we may take the Hive-bees*, so remarkable for their elevated instincts and industrious habits. A swarm of bees consists, first, of females whose sexual organs remain permanently in an undeveloped condition, usually called the *workers* (fig. 173, A); secondly, of perfect males or drones (C); and thirdly, of a solitary fertile female, called *the queen* (B), which gives birth to all the progeny of the hive; and thus, instead of 20,000 or 30,000 eggs being furnished by every one of as many females, one female only is permitted to be instrumental in perpetuating the species.

(905.) The Termite Ants likewise, were it not for a similar restriction, would soon, by their overwhelming increase, depopulate whole regions of the earth, and render the countries in which they are met with absolutely uninhabitable by their extreme voracity. A community of

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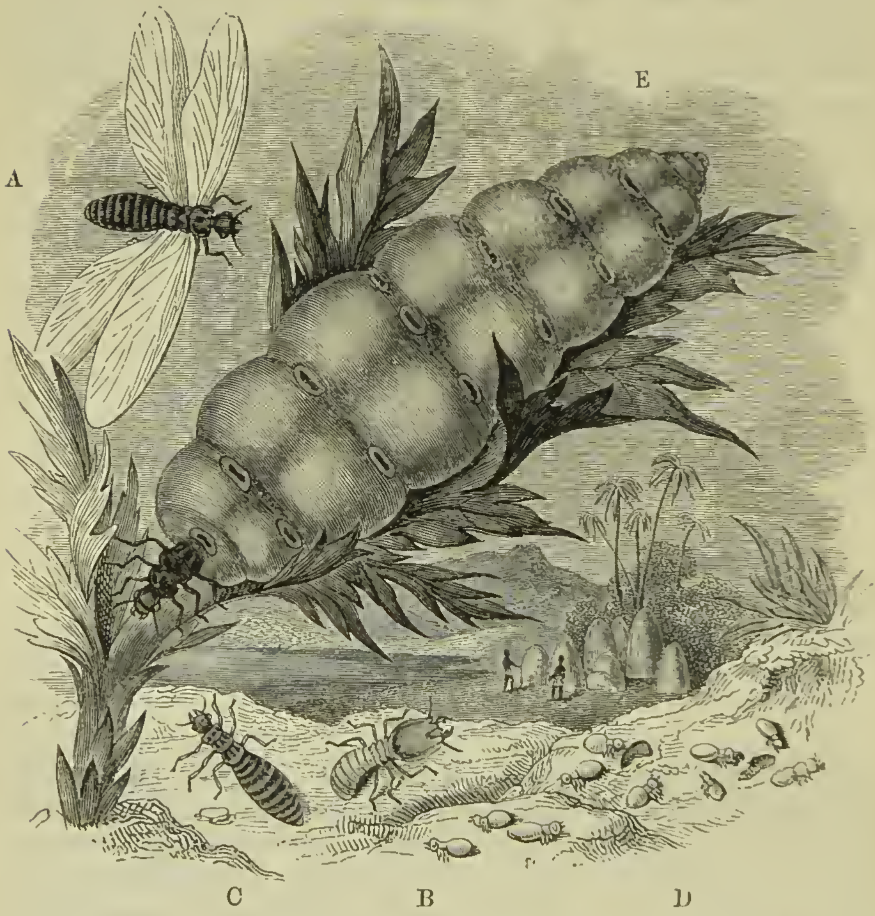
* For ample details concerning the habits of these interesting creatures, the reader is referred to Dr. Bevan's work 'On the Honey-bee; its Natural History, Physiology, and Management.' 1 vol. 12mo. London.

Termites is said to consist of five different classes: namely, winged males and females (fig. 174, A); apterous neuters, or soldiers, which have large heads furnished with strong projecting mandibles (B); unwinged pupæ, having a smaller head, and the rudiments of wings only (C); and, lastly, of similarly-formed *larvæ*, or *workers* (D), differing from the pupæ only in wanting the rudiments of wings. The following is a brief history of the establishment and growth of a colony of these insects,

Fig. 174.



Colony of Termite Ants. A, Winged male. B, Soldier. C, Wingless pupa. D, Workers. E, Queen Termite enormously distended with eggs.

as narrated by Burmeister *. At the termination of the hot season, the young males and females disclosed in a nest quit it, and appear upon the surface of the earth, where they swarm in innumerable hosts, and pair. The busied workers then convey a chosen male and a female back into the dwelling, and imprison them in the central royal cell, the entrances to which they decrease and guard: through these apertures the imprisoned pair then receive the nutriment they require. The male now, as amongst all other insects, speedily dies after the impregnation of the female has been effected; but the female from this period begins to swell enormously from the development of her countless eggs, and by the time she is ready to commence laying, her abdomen is about 1500 or 2000 times larger than all the rest of her body (fig. 174, E). During the period of this swelling, the workers remove the walls of the royal apartment, uniting the nearest cells to it; so that in proportion to the increase of the body of the queen, the size of the abode she inhabits is also increased. She now commences laying eggs, and during the process the abdomen exhibits a continual undulatory motion, produced by the peristaltic movement of the egg-ducts; while the workers convey away the eggs as they are laid, and deposit them in the distant rearing-cells of their wonderful habitation. The reader will be able to form some idea of the relative proportions and outward appearance of the edifices erected by these comparatively minute beings by the group of their citadels represented in the background of the figure; but to describe them more minutely would lead us into details unconnected with our subject*.

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* Manual of Entomology, p. 535.

(906.) The eggs of these little animals vary much in shape and external configuration; so that, from the beauty of their forms and exquisite sculpture, some of them are interesting objects for the microscope.

(907.) We have already spoken concerning the metamorphoses which insects undergo during the progress of their development from the form under which they first leave the egg to their mature condition, when they become fertile, and, in most instances, acquire those instruments of flight so generally characteristic of their perfect state. Before entering upon a more minute inquiry concerning the physiological principles upon which the important changes in question depend, and the phenomena attending the process, it will be advisable to cite a few more examples illustrative of the most interesting varieties of metamorphosis signalized by authors. Fabricius distinguishes five different kinds of metamorphosis, and has applied a different name to each.

(908.) The first class comprises all insects of which the larva is a maggot entirely deprived of legs, that, after having changed its skin, or *moulted*, a certain number of times, becomes, previous to its last change, encased in an oval horny sheath, or pupa-case, whereon not the least trace of the limbs of the mature insect is to be detected. Such pupæ are absolutely without the power of motion, and are distinguished by the name of *coarctate*. Examples of this sort of metamorphosis are met with in the common House-flies (*Muscidæ*); and the forms of their larvæ and pupæ are familiar to every one.

(909.) Of the second kind, technically named *obtected*, the Lepidoptera furnish well-known instances. The changes which occur in the development of the Silkworm, represented in the annexed figure (fig. 175), may readily be witnessed. In such insects the full-grown caterpillar, having enclosed itself in a silken ball, throws off its last skin, and becomes a quiescent pupa; but while in this state, the position of the rudiments of the wings and other appendages of the perfect insect is strongly indicated upon the exterior of the chrysalis (A), though these parts are still closely wrapped up in the external covering.

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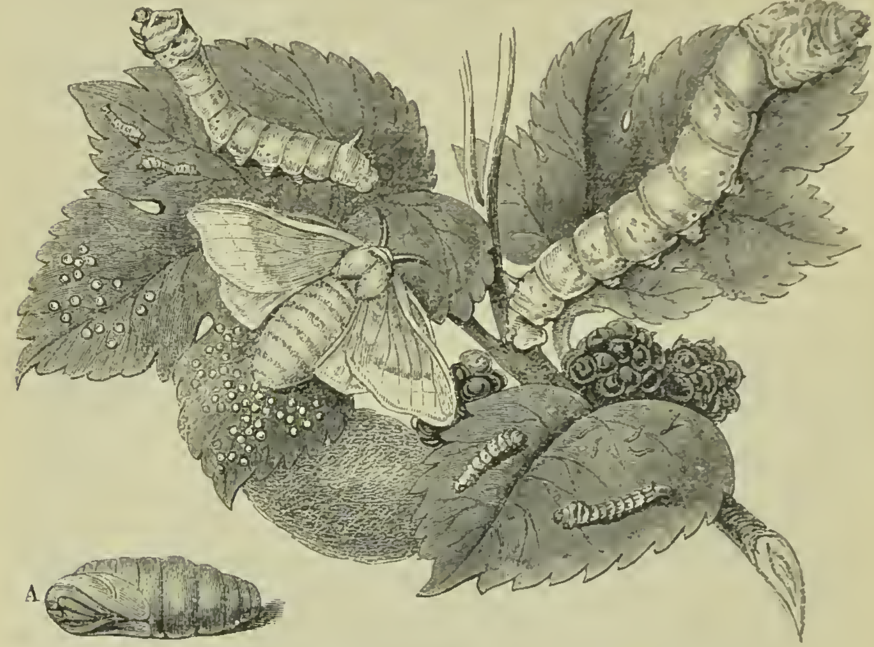
* *Vide* Smeathman, Phil. Trans. vol. lxxi. 1781.

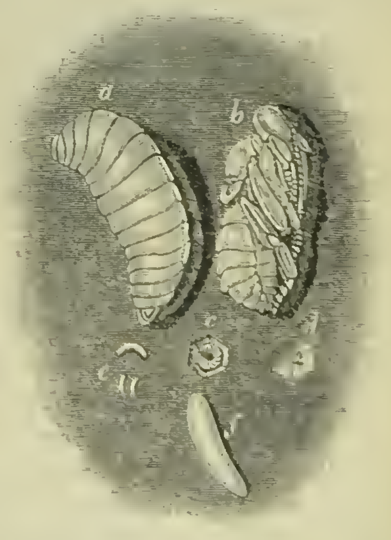
Fig. 175.



Metamorphoses of the Silkworm: A, Chrysalis.

(910.) The third form of metamorphosis, called *incomplete*, is seen in the Hymenoptera, and in many Coleopterous insects. The maggot, in such tribes as exhibit this kind of change, is in some species a simple worm, deprived of feet or other external organs; in others these parts exist in a very imperfect condition: in the pupa, however, the form of the legs and antennæ is perfectly distinct, and even the wings may be seen as rudiments projecting from the thorax. This kind of chrysalis we have seen in the Cockchafer (fig. 149, B), in which the grub (C) possessed feebly-developed legs; and in the Hive-bee.

Fig. 176.



Metamorphoses of the Hive-bee: *a*, full-grown larva: *b*, pupa: *c*, *d*, *e*, *f*, eggs and young, newly hatched.

although the larva (fig. 176, *a, c, d, e, f*) has no legs or exterior appendages, in the pupa (*b*) all the limbs of the perfect Bee are recognized with the utmost facility. Yet all these organs are still enclosed in distinct cases (*thecæ*), to each of which names have been applied by entomological writers; and it is only on throwing off the integument which thus imprisons the mature insect that the Bee makes its appearance in a capacity to begin its active and industrious existence in the winged state.

(911.) Those insects whose larva only differs from the imago in not being possessed of wings (fig. 145, c), Fabricius regarded as undergoing a *semicomplete* metamorphosis; and when the perfect insect did not acquire wings at all, but precisely resembled the pupa, he called the latter *complete*.

(912.) But there are innumerable examples of metamorphosis which will not conform to any of the above definitions; and in some of them the phenomena exhibited are not a little remarkable. We have already mentioned the changes which the Dragon-fly undergoes (figs. 146, 147), and have seen that in this case there is no very striking resemblance between the pupa and the adult creature, but, on the contrary, that very wonderful changes occur during the last stage of the metamorphosis. The pupa lives in water; and, besides six jointed legs adapted to climb the stems of subaquatic plants in search of prey, is possessed of a very peculiar locomotive apparatus whereby it can propel itself through the element which it inhabits. Appended to the posterior extremity of the abdomen we find three or five leaf-like appendages, which the creature continually opens and closes, and at the same time takes in a quantity of water, sufficient to fill the muscular termination of the rectum, which is expanded for the purpose; this water is, at intervals, forcibly expelled, mingled with bubbles of air, and thus effects the propulsion of the animal by a mechanism which human ingenuity has imperfectly attempted to imitate.

(913.) But the contrivance above mentioned is also made subservient to respiration; for, from the observations of Cuvier*, it appears that the interior of the rectum exhibits to the naked eye twelve longitudinal lines of black spots arranged in pairs; and these, when examined under the microscope, are found to be composed of little conical tubes, from which branches go off to join the principal longitudinal tracheæ that distribute air through the body.

(914.) Another remarkable peculiarity is met with in the structure of the mouth of these aquatic larvæ; for the oral apparatus here forms an instrument of prehension adapted to seize prey at a distance, and constitutes, in fact, a kind of projectile forceps of a very curious construction. Let the reader contrast the following description with that already given of the oral organs of the Dragon-fly (§ 818), and observe the remarkable difference:—"Conceive," says Kirby and Spence*, "your under lip to be horny instead of fleshy, and to be elongated perpendicularly downwards, so as to wrap over your chin and extend to its bottom; that this elongation is then expanded into a triangular convex plate attached to it by a joint, so as to bend upwards again, and fold over the face as high as the nose, concealing not only the chin and the first-mentioned elongation, but the mouth and part of the cheeks: conceive, moreover, that to the end of this last-mentioned plate are fixed two other convex ones, so broad as to cover the whole nose and temples; that these can open at pleasure, transversely, like a pair of jaws, so as to expose the nose and mouth, and that their inner edges, where they meet, are cut into numerous sharp teeth or spines, or armed with one or more long and sharp claws;—you will then have as accurate an idea as my powers of description can give of the strange conformation of the lip in the larvæ in question, which conceals the mouth and face precisely as I have supposed a similar construction of your lip would do yours. You will probably admit that your own visage would present an appearance not very engaging while concealed by such a mask: but it would strike still more awe into the spectators were they to see you first open the two upper jaw-like plates, which would project from each temple like the blinders of a horse; and next, having, by means of the joint at your chin, let down the whole apparatus and uncovered your face, employ them in seizing any food that presented itself and conveying it to your mouth. Yet this procedure is that adopted by the larvæ provided with this strange organ. While it is at rest, it applies close to and covers the face. When the insects would make use of it, they unfold it like an arm, catch the prey at which they aim by means of the mandibuliform plates (fig. 147, A), and then partly refold it, so as to hold the prey to the mouth in a convenient position for the operation of the two pairs of jaws with which they are provided."

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* Mém. de la Soc. d'Hist. Nat. p. 48.

(915.) The metamorphoses of the Gnat (*Culex*) are not less interesting. The female deposits her eggs upon the surface of the water, in which her offspring are destined to pass the earlier periods of their existence, gluing the ova together at the moment of their extrusion, so as to unite them into a boat-like mass (fig. 177, A) of such beautiful construction that the little bark swims secure from injury even during the roughest weather. The individual eggs are of a conical form (fig. 177, B, *a*, *b*, *c*), and are closed at their inferior extremity by a kind of lid (*d*), provided to give egress to the mature embryo. The larva (C), represented upon a magnified scale at E, bears not the slightest resemblance to the perfect insect, and is provided with a singular modification of the respiratory apparatus adapted to its habits. The head is large, and carries two ciliated organs (*g g*), which by their movements bring food towards the mouth; the thorax is even larger than the head, and

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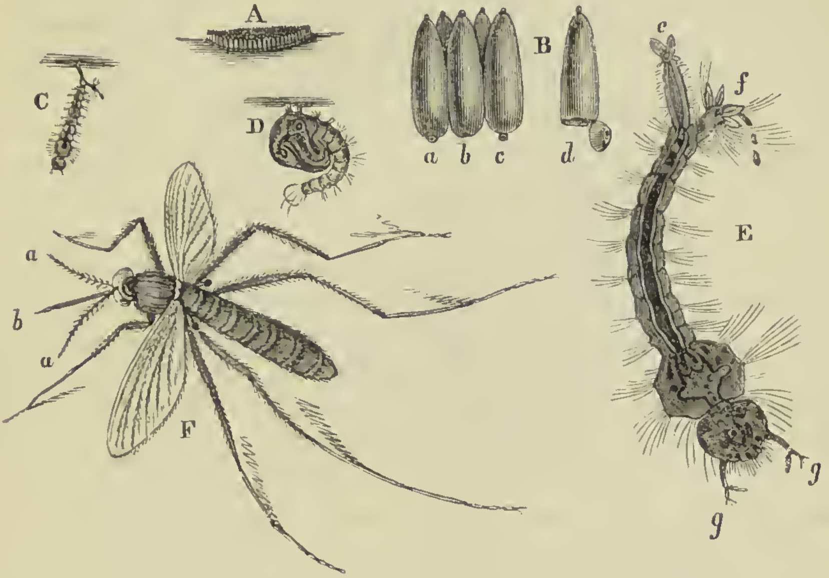
* Introd. to Entom. vol. iii. p. 126.

is furnished with fin-like bunches of minute hairs, as likewise are the segments of the abdomen. To the extremity of the tail is appended a group of moveable leaflets or fins, so disposed that by their action they sustain the larva at the top of the water, where it generally remains suspended with its head downwards. Such a position would obviously render respiration impossible was there not a corresponding arrangement of the breathing organs to allow of free communication with the air. For this purpose, the respiratory tracheæ are found to be connected with a tube appended to the antepenultimate segment of the abdomen, the perforated extremity of which, being raised above the water, procures from the atmosphere the oxygen required for respiration. After several moults, the larva, having attained its full growth, enters the pupa state, and in this condition still remains an inhabitant of the water, and occupies a position near the surface. A remarkable change, however, is visible in all parts of its structure. The head and thorax (fig. 177, D) are consolidated into one large mass, under which the lineaments of the mature insect may be detected; while the tail still continues to be the agent employed in natation. The condition of the respiratory organs, moreover, is completely altered: the tube fixed upon the antepenultimate segment of the larva has totally disappeared, and instead of it we find two tubes appended to the back of the thorax; these, although they perform the same office as the anal pipe of the larva, are thus displaced in order to correspond with the altered posi-

Fig. 177.

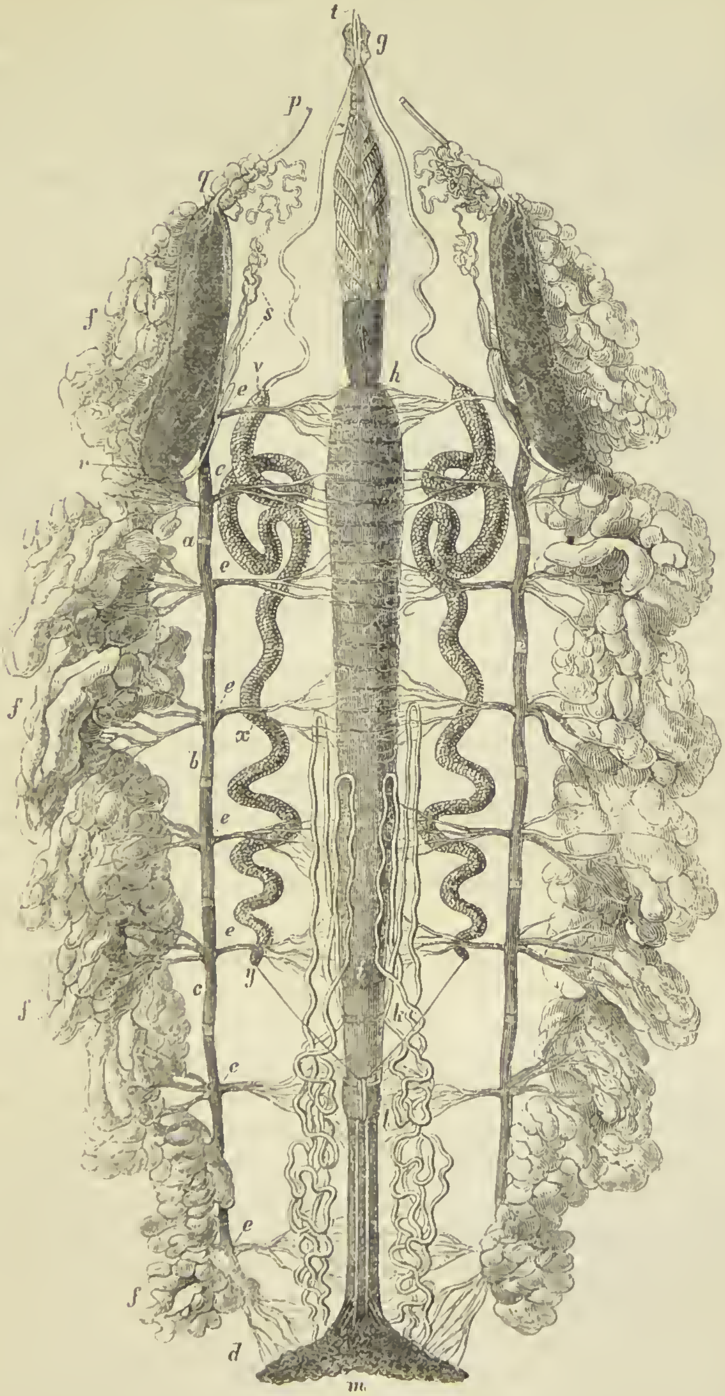


Metamorphoses of the Gnat (*Culex pipiens*):—A, Boat of eggs. B, *a*, *b*, *c*, some of the eggs magnified; *d*, another, showing the lid open for the escape of the larva. C, Larva. D, Pupa. E, Larva magnified, showing—*e*, the respiratory tube; *f*, the anal fins; *g g*, the antennæ. F, the perfect insect, magnified: *a a*, antennæ; *b*, rostrum.

tion in which the animal now swims,—the back of the thorax, and not the tail, being nearest to the surface, as represented in the drawing (D). The necessity for this change of posture, and consequent removal of the apparatus for taking in air from one part of the body to another, will be at once obvious when we consider the circumstances under which the perfect insect, having completed its development, emerges from its pupa investments and enters upon an aërial existence. The problem to be solved is, how shall the mature gnat escape from the water without being wetted? and when we consider that neither the larva nor the pupa possesses instruments of locomotion capable of enabling it to leave its native element by crawling on shore, the difficulties attending the change appear almost insurmountable. It is evident that, while swimming in the position in which the larva floats (fig. 177, c), the last change could not by possibility be accomplished, as the bursting of the integument would at once admit the water to the submerged gnat, and drown it at the moment of its birth; but by the new arrangement the metamorphosis is easily effected, and that in a manner so beautiful, that it is hard to say which is most admirable, the simplicity of the contrivance, or the perfection with which the object is accomplished. No sooner has the encased imago become fitted for its escape than the pupa, rendered more buoyant, raises its back above the surface; the protruded portion of the pupa-case soon dries, and gradually begins to split in a longitudinal direction, so as to form by its expansion a boat wherein the gnat swims upon the top of its native pond; and sustained in this frail bark, formed by its late skin, it gradually extricates its legs and wings from their coverings, and is kept perfectly dry until the expansion of its instruments of flight enables it to soar into the air and quit for ever the raft so singularly provided for its use.

(916.) Having thus become acquainted with the various conditions under which insects arrive at maturity, and the principal forms that they exhibit during the different stages of the metamorphosis, the reader will be prepared to investigate more minutely the changes in progress during the process, and the gradual development of the organs which successively make their appearance. On examining the viscera of a *Caterpillar*, they are found scarcely at all to resemble those of the Butterfly or Moth, into which a larva of this description is ultimately matured. The jaws (fig. 180, *b b*), widely different, both in structure and office, from the proboscis which represents them in the perfect insect (fig. 160), are strong and horny shears adapted to cut the leaves of vegetables and other coarse materials used as food; the œsophagus (fig. 178, *g h*) is strong, muscular, and capacious; and the stomach (*h i*), in capacity corresponding with the extraordinary voracity exhibited by the larva, passes insensibly into a wide intestine (*l m*). the line of separation being only indicated by the entrance of the biliary vessels (*k*) that wind in numerous convolutions around the posterior half of the alimentary canal. It is sufficient to contrast this arrangement

Fig. 178.



Viscera of a Caterpillar: *g h*, œsophagus; *h i*, stomach; *k*, hepatic vessels; *l m*, intestine; *q*, *r*, salivary glands; *p*, salivary duct; *a b c*, longitudinal tracheal trunks; *d*, *e e e e*, air-tubes distributed to the viscera; *f f f*, the epiploon or fat-mass; *v x y*, silk-secretors; *z*, their excretory ducts, terminating in *t*, the spinneret or *fusulus*.

of the digestive organs with what we have already described in the Butterfly (fig. 160), to appreciate the amazing dissimilarity: it would be difficult, indeed, to imagine, did not anatomy convince us of the fact, that the digestive apparatus of the imago, with its slender œsophagus, dilated crop, short sacculated stomach, long and convoluted small intestine, and capacious colon, was derived from a gradual modification of such viscera as those we have just been considering. The salivary glands of the Caterpillar (fig. 178, *q*, *r*) are large cylindrical cæca; and their ducts (*p*) pour into the mouth an abundance of saliva proportioned to the coarse nature of the materials used as food.

(917.) The sides of the body are traversed by the wide longitudinal tracheæ (*a b c*), that communicate on the one hand with the lateral spiracles, and on the other give off at regular intervals the air-tubes (*d*, *e e e e*), which ramify most minutely over all the viscera, and convey the atmospheric air throughout the entire system.

(918.) Besides the above organs, there are other viscera, which, although of considerable importance to the Caterpillar, would be utterly useless to the imago, and consequently are more or less completely wanting in the mature state.

(919.) The whole body of the larva is filled with a peculiar fatty tissue (fig. 178, *f f f*), called by entomologists the *rete*, *epiploon*, or *fat-mass*. This material, found in great abundance in mature and well-fed larvæ, consists of an oily or greasy substance enveloped in a most delicate cellulosity, and seems to correspond to the fat of higher animals, like which it is indubitably a product of digestion, and a repository of superabundant nourishment, stored up, no doubt, for the sustenance of the animal during its helpless condition in the dormant or pupa state—serving, like the fat of hibernating quadrupeds, for food during the confinement of the imago.

(920.) But the most remarkable peculiarity of the larvæ under consideration is the presence of an apparatus employed for producing a tenacious thread of extreme delicacy, appropriated by different species to various purposes. In many cases (fig. 148), it is made subservient to locomotion; and by its assistance, as by a rope, the larva can suspend itself from any object, or let itself down from one branch to another in search of food. The most important uses, however, to which this thread is applied are connected with the concealment and protection of the quiescent and defenceless pupa; either furnishing the means of suspending the chrysalis in a place of safety* (fig. 179), or, as is the case with the Silkworm (fig. 175), supplying the material with which the caterpillar encases itself preparatory to throwing off the last skin of the larva. The thread of the last-named insect, the Silkworm, is of great tenacity; and, notwithstanding its fineness, may be wound off from the cocoon in a continuous thread, forming the important article of commerce, *silk*.

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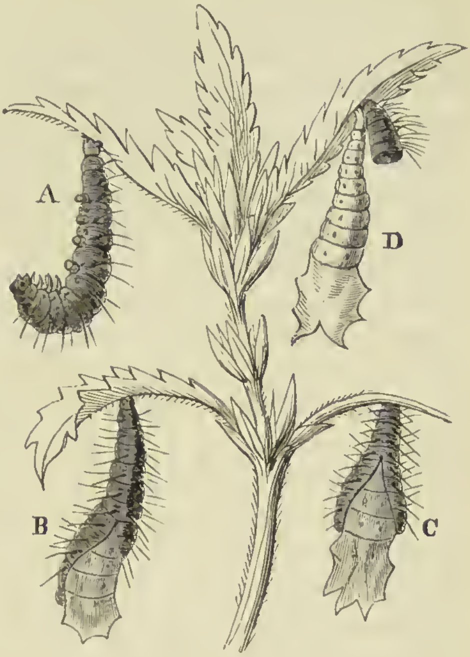
* For a most amusing account of the manner in which some chrysalides manage, without any external limbs, to suspend themselves by the tail in a position of security, the reader is referred to Kirby and Spence, vol. iii. p. 207. Fig. 179 (in the next page) illustrates the different steps attending the process. The larva (A), having spun some loose silk, and fixed it upon the under side of a leaf or other suitable object, suspends itself therefrom by its hind-legs. The skin of the caterpillar then gradually splits down the back (B, C), and is slowly pushed upwards towards the tail of the chrysalis. The

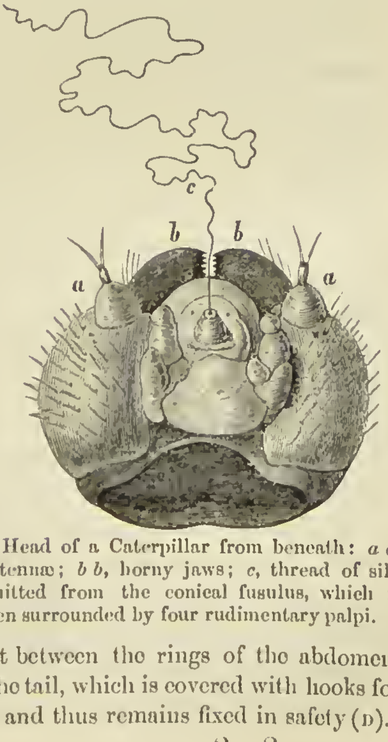
Fig. 179.



Process whereby a chrysalis becomes suspended by the tail. (See note, p. 354.)

(921.) Nothing can be more simple than the apparatus provided in caterpillars for the production of this valuable commodity:—Placed on each side of the intestine are two long and tortuous secreting cæca (fig. 178, $v\ x\ y$), that separate from the surrounding juices of the body a tenacious viscid fluid, which is liquid silk. The viscid secretion thus formed is in the Silkworm of a golden-yellow colour, and is conveyed by the excretory ducts of the secerning organs (z) to the labium or under-lip, where the ducts terminate at the base of a tubular instrument, the *fusulus* or *spinneret*, through which the silk is drawn (fig. 180, c). The *fusulus* of the Silkworm, represented in the annexed figure upon an enlarged scale, is a simple nipple-shaped prominence, perforated at its extremity, and surrounded by four rudimentary palpi. When about to spin, the larva, by placing the extremity of its spinneret in contact with some neigh-

Fig. 180.



Head of a Caterpillar from beneath: *a a*, antennæ; *b b*, horny jaws; *c*, thread of silk emitted from the conical fusulus, which is seen surrounded by four rudimentary palpi.

pupa now lays hold of the old skin, nipping it between the rings of the abdomen, and hanging in this posture inserts the apex of the tail, which is covered with hooks for the purpose, into the silk previously deposited, and thus remains fixed in safety (D).

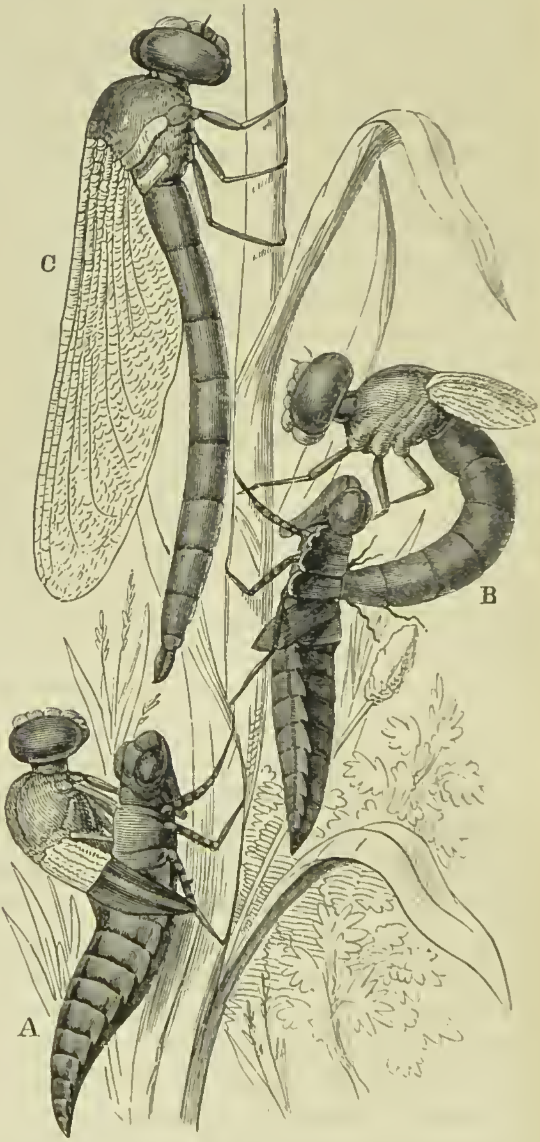
bouring object, allows a minute drop of the glutinous secretion to exude from its extremity, which, of course, adheres to the surface upon which it is placed: the head of the Silkworm being then slowly withdrawn, the fluid silk is drawn out in a delicate thread through the aperture of the spinneret, its thickness being regulated by the size of the orifice, and, immediately hardening by the evaporation of its fluid parts, forms a filament of silk, which can be prolonged at the pleasure of the animal until the contents of its silk-reservoirs are completely exhausted.

(922.) Such is the structure of the larva of a Lepidopterous insect; and the arrangement of its internal viscera, when arrived at maturity, has been already described. We have yet, however, to mention the series of phenomena observable during the progress of its growth, and the mode of its expansion from the minute size that it exhibits on leaving the egg to the full dimensions which it ultimately acquires. In order fully to understand the circumstances connected with this part of our subject, it is necessary to premise that the outer integument of most larvæ is of a dense corneous texture, coriaceous in some parts, but quite hard and horny in others. In the second place, it is but very slightly extensible; and, moreover, as is always the case with epidermic structures, it is not permeated by any vascular apparatus, and consequently is absolutely incapable of growth when once formed. This epidermis encases every portion of the larva: the body, the legs, the antennæ, the jaws, and all external organs are closely invested with a cuticular envelope, such as, from its want of extensibility, would form an insuperable obstacle to development, were there not some extraordinary provision made to meet the necessity of the case. The plan adopted is, to cast off at intervals the old cuticle by a process termed *moulting*—an operation which is repeated several times during the life of the insect in its larva condition, and is accomplished in the following manner:—The caterpillar becomes for a few days sluggish and inactive, leaves off eating, and endeavours to conceal itself from observation. The skin, or more properly the cuticle, becomes loosened from the subjacent tissues, and soon a rent appears upon the back of the animal, which gradually enlarges in a longitudinal direction, and the imprisoned insect, after a long series of efforts, at length succeeds in extricating itself from its old covering, and appears in a new skin of larger dimensions than the one it replaces, which, however, in all other particulars it closely resembles. With the old epidermis the larva throws off all external appendages to the cuticle: the horny coverings of the jaws, the corneæ of the eyes, the cases of the claws, are all removed; and many writers have even found attached to the exuviæ an epidermic pellicle that had formed a lining to the rectum, and delicate prolongations of the cuticle derived from the interior of the larger ramifications of the air-tubes. Absurd, indeed, have been the explanations given by various writers of the nature of the process under consideration. Swammerdam and Bonnet, nay, even our own illustrious entomologists Kirby and Spence, believed that even at the birth of the caterpillar all these skins existed ready-formed one beneath the other, and that the most external being removed at intervals displayed in succession the skins placed underneath. Surely the advocates of this extraordinary theory could scarcely have reflected upon the real object of the moults in question (namely, to provide a succession of larger coverings proportioned to the continually increasing bulk of the larva) when they advocated this strange doctrine, alike at variance with observation and sound physiological principles. The epidermis and all cuticular structures are mere secretions from the subjacent cutis or true skin; and it can be no more necessary to suppose the pre-existence of so many skins in order to explain the moults of a larva, than to imagine that because, when in our own persons the cuticle is removed by the application of a blister, a new layer of epidermis is again and again produced, man should possess as many skins, one beneath the other. Nothing, in fact, can be more simple and free from the miraculous than the whole process: at certain periods, when the old cuticle has grown too small for the rapidly-enlarging dimensions of the insect, it becomes gradually loosened and separated from the vascular and living skin or cutis by which it was originally secreted; and, a new secretion of corneous matter taking place, a fresh and more extensive layer of cuticle is slowly formed, and then the old, dry and dead epidermis, being quite detached, is split by the exertions of the larva, and the newly-secreted layer placed beneath it appears. When the old skin is at length completely thrown off, the newly-formed one soon hardens by exposure, and the re-clothed caterpillar assumes again its former activity and habits.

(923.) Neither is the change from the larva to the pupa or chrysalis less easily explained, although regarded by our forefathers as being so mysterious and astonishing a phenomenon. According to the hypothesis above alluded to, after removing three or four skins in the embryo larva, the anatomist ought to have arrived at the totally different pupa-case ready-formed, and only waiting for the removal of the coats above it to exhibit its characteristic form. Leaving, however, such visionary notions, let us examine the real nature of this portion of the metamorphosis. The reader will bear in mind that, whatever the form of the exterior or epidermic crust, it is merely a dead and extra-vascular secretion, unchangeable when once deposited. But the living skin or *cutis*, beneath it, is, *during the whole process of the metamorphosis*, undergoing great and important changes—increasing only in *size* during the larva condition, but when perfectly organized, developing itself at different points, and expanding into variously-shaped organs which did not previously exist. In the Dragon-fly, for example (fig. 147), when the cutis had become expanded to its mature *larva* condition, it secreted from its surface the external epidermic crust which gives form to the larva (B): this outward integument remains, of course, unchanged when once formed, and retains the same appearance during the whole period of the existence of the insect in its larva state; but underneath this cuticle, and consequently concealed from observation, the growth of the living *dermis* still goes on, and important organs begin to appear, which had no existence when the last larva-investment was secreted. The wings have sprouted as it were from the shoulders, and already have attained to a certain growth; the whole integument of the larva becomes useless, and a new one is wanted; the process already described is repeated,—the old cuticle becomes detached from the surface of the body, and the cutis begins to secrete for itself a new covering moulded upon its own shape. The newly-formed wings, therefore, and other newly-developed processes of the *dermis*, secrete horny coverings for themselves in the same manner as other parts of the surface of the body; and thus, when the insect leaves its old skin, and once more escapes from confinement, it presents to view the wing-cases which distinguish the pupa.

(924.) Whatever may be the form of the pupa, its covering is secreted in a similar way; it is the living and vascular skin which, though concealed, continually grows more perfect in its parts; and the cases secreted by it at distant intervals correspond in shape with the different phases of its development.

Fig. 181.



Metamorphosis of the Dragon-fly. A, B, escape of the imago from its pupa-case; C, expansion of the, as yet, undeveloped wings.

(925.) After having attained the pupa state, the last steps of the process are completed, and the dermic system becomes fully developed in all its parts. The oral apparatus attains its perfect condition; the wonderfully-elaborate structure of the eyes is completed; the antennæ assume their full development; the legs, enclosed in those of the pupa, attain their mature form; and the wings, which have been continually growing, although concealed in the wing-cases of the pupa, acquire their ultimate size: the perfect insect is ready for liberation, and, enclosed in its last covering, creeps out of the water in which it has so long resided, to enter upon a new state of existence. Fixing itself upon some plant in the neighbourhood of its birthplace, the imprisoned Dragon-fly splits its pupa-case along the back (fig. 181, A), and slowly extricates its head and body; it then draws its wings from their coverings, and its legs from those of the pupa as from cast-off boots; and at length (fig. 181, B), getting its body from its now useless covering, it becomes entirely free. The wings, before soft and crumpled, slowly expand (fig. 181, C); the nervures harden; the extended membranes dry; and in a short time the winged tyrant of the insect world (fig. 146) commences his aërial career.

(926.) A strong argument in favour of the above views concerning the production of successive skins from the dermis is derived from the phenomena attending the *cure of wounds* in insects. If a perfect insect be wounded, the wound is never healed at all; and if a larva or pupa is similarly injured, the wound remains uncicatrized until the next moult, when the newly-formed integument is found to exhibit no traces of the injury. The secreted and extra-vascular cuticle cannot cicatrize; but the living and vascular dermis is not only able to repair injuries inflicted upon itself, but, in secreting the next investment, to obliterate all indications of their occurrence.

(927.) The changes above described are produced by the progressive development of the dermic or tegumentary system, the parts of which, as we have already seen, becoming strengthened and consolidated by degrees, ultimately acquire that density of structure which the external skeleton of the insect exhibits in its perfect or *imago* state. But while this extraordinary metamorphosis is going on externally, other changes not less important are in progress in the interior of the body. The size of the alimentary canal, and the shape, proportionate dimensions, and general arrangement of the different parts composing it are secretly and imperceptibly undergoing variations in accordance with the altered necessities of the animal. We have already seen a conspicuous example of this in *Lepidopterous* insects, § 916; and in other orders equally striking instances might easily be selected. One of the most remarkable is met with in many *Hymenoptera*, as, for example, in Bees (*Apis*), Wasps (*Vespa*), and Ant-lions (*Formica leo*), as well as in most of the *Ichneumonidæ*. In all these genera, the larva being concealed in a close cell during its development, under circumstances which would render the evacuation of excrementitious matter an obvious inconvenience, both the larva and pupa (fig. 176) are entirely without either intestinal canal or anal orifice,—what little excrement is produced by the digestion of the highly nutritive substances wherewith these larvæ are fed being collected in a blind cavity or cæcum placed behind the stomach, until the accomplishment of the last change—at which period, the insect, liberated from its confinement, becomes provided with a pervious intestine, and able to get rid of feculent matter.

(928.) The fat-mass (§ 919), which at the close of the larva state has reached its maximum of development, is gradually absorbed during the concealment of the insect in its pupa-case, its nutritive portions being no doubt appropriated to the nourishment of the pupa; so that in the mature insect the fatty material has almost entirely disappeared, nothing being left in its place but the dense cellular web in which the fat had been deposited.

(929.) The silk-secreting apparatus of such genera as possess the means of spinning a silken thread is peculiar to the larvæ; and, after the commencement of the pupa state, no traces of its previous existence are to be detected.

(930.) But while the above-mentioned organs disappear, others become developed; and the perfect insect is found to possess viscera for which a skilful anatomist might seek in vain in the earlier stages of its existence. The *generative system* appears, at first, to be absolutely wanting in the larva; but Herold*, after much patient investigation, succeeded in detecting the undeveloped rudiments of the future sexual organs both of the male and female. It is during the maturation of the pupa that these important parts expand; and before the disclosure of the imago they are found to have attained their complete proportions, so as to be ready to perform their functions as soon as the expansion of the wings endows the insect with means of locomotion sufficiently perfect to ensure the due dispersion of the species.

(931.) It is in the nervous system, however, that the most interesting phenomena are observable; and in the lessons afforded by watching the correspondence between the state of the animal during the several phases of its existence and the development of the nervous ganglia, the physiologist cannot fail to recognize those great and general principles upon which our arrangement of the animal creation is based. In the worm-like larva the ganglia are numerous, but of small dimensions—too feeble to be capable of animating powerful limbs, or of appreciating impressions from the organs of the higher senses; the animal is, in fact, precisely in the condition of an ANNELIDAN, which it would seem to represent. External limbs are therefore absolutely wanting in many larvæ; in others they are represented by short and stunted appendages; and even in the most perfect, or hexapod larvæ, they are feeble instruments in comparison with those of the mature imago. The senses exhibit equal imperfection; and eyes are either entirely wanting, or are mere ocelli—simple specks, exhibiting the lowest possible organization of a visual apparatus. But as the growth of the larva goes on, a change in the arrangement of the nervous system is perpetually in progress. The series of nervous cords connecting the different pairs of ventral ganglia in the larva (fig. 182, A) become flexuous as the insect attains the pupa state; the whole chain becomes shorter; the brain, or encephalic ganglion, increases in its proportionate dimensions; and, moreover, several ganglia, originally distinct, coalesce, and form larger and more powerful masses (fig. 182, B). This coalescence of the ganglia, which takes place more especially in the thoracic region, is evidently a preparation for the concentration of greater power and activity in this part of the body; and although in inactive *chrysalides* this change is not as yet visible by its effects, in the active forms even the pupa is

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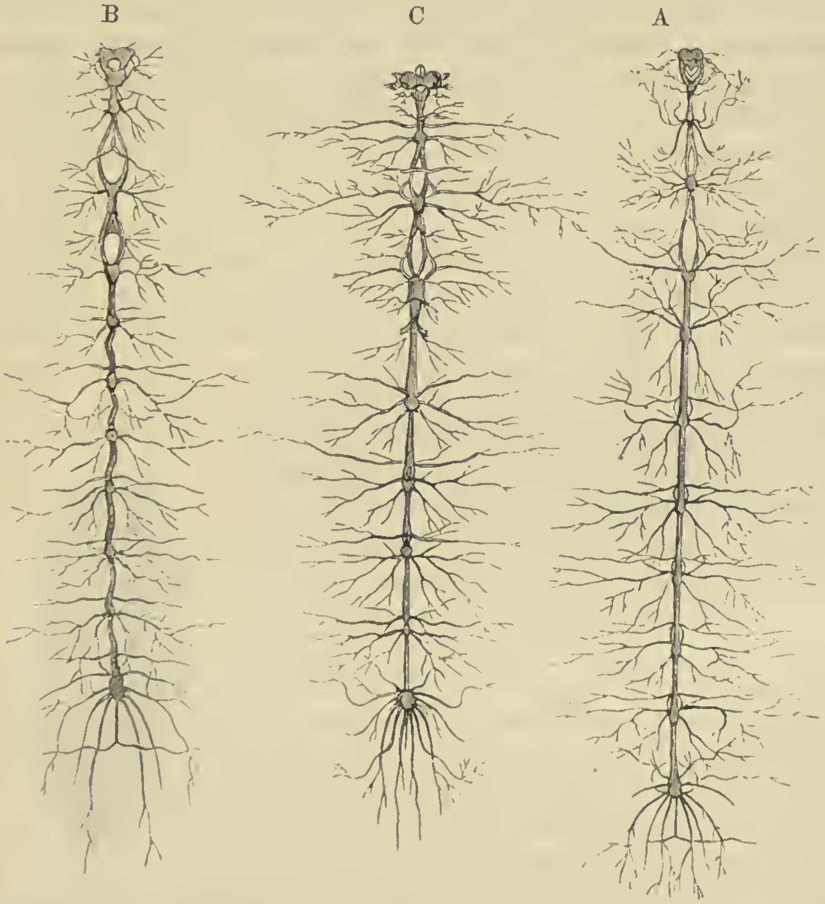
* Entwickelungsgeschichte der Schmetterlinge. 1815. 4to.

Fig. 182.

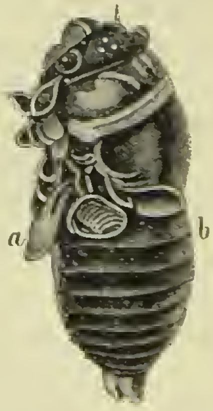


Changes which the nervous system undergoes during the progress of Insect metamorphosis. A, Nervous system of the Larva. B, that of the Pupa. C, that of the Imago or perfect insect.

distinguished from the larva by a considerable increase of vigour and energy in its movements. In the *imago* the concentration of the nervous centres is carried to that extent which is adapted to the necessities of the mature state: their number is still further reduced (fig. 182, c); their size, in the thorax especially, considerably increased; and the brain, now arrived at its maximum of development, is furnished with the wonderful apparatus of eyes, and other instruments of the senses, which heretofore would have been absolutely useless, but now, with the expansion of the brain, have become suited to the more exalted faculties of the insect.

(932.) Many insects are capable of producing audible sounds; and sometimes the noises they make are exceedingly shrill, and may be heard at some distance. Such sounds originate from various causes in different tribes, and it is not always easy to detect the mode of their production. In many Beetles they are caused by rubbing different parts of their dense integument against each other; and the chirping of several *Orthoptera* seems to have a similar origin: the acute note that these insects utter is apparently produced by friction, the edges of their hard pergamentaceous wings being either scraped against each other, or against the long and serrated edges of their thighs. The buzzing and humming noises heard during the flight of many genera result from the forcible expulsion of the air as it streams through the respiratory spiracles, whose orifices Burmeister imagines are furnished with vibratory laminæ, to the rapid movements of which the noise may be due. In the genera *Gryllus* and *Cicada* among the Orthoptera, however, there is a peculiar apparatus specially provided for the production of the loud chirping to which such insects give utterance. Upon the first segment of the abdomen, covered by a broad moveable plate (fig. 183, *a*), there is a large aperture, wherein a tense plicated membrane is observable. This membrane is acted upon internally by certain muscles able to throw it into rapid vibration, and thus give rise to the sound in question.

Fig. 183.



Musical apparatus of *Cicada*: *a*, moveable horny plate, drawn aside to display the plicated membrane; *b*, rings of the abdomen.

(933.) One other point connected with this interesting class of animals requires brief notice. Many insects are endowed with the faculty of emitting phosphorescent light, which is in some species exceedingly brilliant. The *Elateridæ* among Beetles are pre-eminently luminous; and in them the light seems to be principally given out by two oval spaces upon the thorax, which in the dead insect are of a greenish hue: during life, some species (*Elater noctilucus*) are so strongly phosphorescent as to enable a person to read a book by passing the animal over the lines. The *Lampyrides* emit a light of great brilliancy; and in Italy, during the summer nights, the groves, illuminated by their incessant scintillations, exhibit a scene equally strange and beautiful. The females of *Lampyris noctiluca* have two large yellowish-white luminous plates upon the ventral surface of the sixth and seventh abdominal rings, and, besides these, two minute organs of a similar description on the eighth or caudal segment. The latter only (and these of a smaller size and greyish transparent hue) are present in the males.

(934.) All the luminous organs, both ventral and lateral, present essentially the same structure, consisting of an investing membrane enclosing a parenchyma composed of tracheæ and nerves surrounding groups of cells so densely filled with white, spherical, minute granules, having an oily aspect when viewed by transmitted light, that no other constituent can be seen in them; and from experiments, as well as the anatomical facts, Kölliker concludes that the luminous organs are a nervous apparatus, whose nearest analogues are to be sought for in the electrical organs of certain fishes*.

CHAPTER XIII.

ARACHNIDA†.

(935.) The Arachnidans, long confounded with Insects, and described as such even by recent entomologists, are distinguished by characters of so much importance from the animals described in the last chapter, that the necessity of considering them as a distinct class is now no longer a matter of speculation. In Insects, the external skeleton presents three principal divisions—the *head*, the *thorax*, and the *abdomen*: but in the Spider tribes, the bloodthirsty destroyers of the insect-world, the separation of the head from the thorax, which, by increasing the flexibility, necessarily diminishes the strength of the skeleton, is no longer admissible; and, the process of concentration being carried a step further, the head and thorax coalesce, leaving only two divisions of the body recognizable externally, viz. the *cephalo-thorax* and the *abdomen*. Insects, in their mature forms, were found to be invariably furnished with only *six* legs, but in the adult Arachnidans eight of these limbs are developed. These characters in themselves would be sufficient to discriminate between the two orders; but when to these we add that in the Arachnidans the eyes are invariably smooth, that the antennæ of Insects are represented by organs of a totally different description, that the sexual apertures are either situated beneath the thorax, or at the *base* of the abdomen, and, moreover, that in the greater number of Arachnidans respiration is carried on in localized lungs (*pulmonibranchiæ*), instead of by tracheæ as in Insects, we need not enlarge further in the present place upon the propriety of ranking the Arachnida as a separate class. These animals may be grouped under three principal divisions,—the first of which is evidently an intermediate type of organization, combining many of the characters of the Insecta with the external limbs and palpi of proper Arachnida.

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* Verhandl. d. Würzb. Phys. Med. Ges. viii. 1857.

† Ἀράχνη, a spider.

(936.) The Arachnida Trachearia, in fact, breathe by means of tracheæ resembling those of Insects, which are so arranged as to convey air to every part of the system; and we may therefore suppose that their circulatory apparatus, as well as their secerning organs, conform more or less to the type of structure met with in the class last described. The Mites (*Acaridæ*) belong to this division, and form a very numerous family, which is extensively distributed. Some are parasitic in their habits, infesting the bodies of insects; and one, the itch-insect (*Acarus scabiei*), is found occasionally upon the human skin. Many live in cheese and other provisions, where they multiply prodigiously; and not a few inhabit leaves, or are found under stones or beneath the bark of trees. Some (*Hydrachna*) are aquatic; but, unfortunately, in all, from their extremely minute size, the investigation of their internal viscera presents so many difficulties, that but little is satisfactorily known concerning their anatomy: even the *pseudo-Scorpionidæ*, which are of larger growth and, although still breathing by tracheæ, approximate most closely to the outward form of the next group, have been very imperfectly examined.

(937.) In the Acaridans, the most remarkable feature of their structure is the complete consolidation or coalescence of the principal divisions of the body, which are always more or less distinct in the other Articulata; for not only do we find in them the head consolidated with the thoracic portion, but the abdomen likewise is swallowed up, as it were, in the general covering of the body. The legs, as in other Arachnidans, are eight in number, and are generally composed of seven articulations, of which the first, which is sometimes adherent and sometimes free, corresponds with the *coxa* of Insects, the second with the trochanter; the third, representing the femur, is often more developed than the rest, whilst the remaining constitute the tibia and the tarsal joints. The last segment of the tarsus, or foot as it might be called, is furnished with two moveable hooks, that can be folded back, and lodged in a slight excavation provided for the purpose.

(938.) In accordance with their structure, which is adapted to the habits of the various races, the feet of the Acaridans may be divided into such as are adapted for feeling (*palpatorii*), in which the ultimate joint is dilated; for walking (*gressorii*); for swimming (*remigantes*).

having the last joint expanded and ciliated, as in some, but not all, of the aquatic tribes; for running (*cursorii*), where it is long and slender; for weaving (*textorii*), in which case the ultimate segment is provided with very short and much-curved hooks, and the antepenultimate with four elongated stiff bristles longer than the foot; and lastly, such as are formed for a parasitic life, or carunculated (*carunculati*), in which, superadded to the hooks, is a caruncle or broad membrane wherewith the creature fixes itself to a smooth surface, something in the same way as the sucker of a Leech.

(939.) The mouth is composed of two moveable pieces called the mandibles, beneath which is a broad plate (*labium*), which is either flat or folded laterally so as to form a kind of gutter, and, moreover, is furnished on each side with a rudimentary palpus. The mandibles are generally free, but in some cases are united together and conjoined with the labial piece, so as to form a short tube or proboscis, near the end of which may be perceived a pair of moveable tooth-like structures, adapted to pierce the substances whence these suctorial races obtain their liquid food. When the mandibles remain entirely free and moveable, they exhibit, as was pointed out by M. Dugès*, three principal modifications in their structure: 1st, they are forcipated (fig. 184), like those of Scorpions; secondly, they may be terminated by a single moveable fang (fig. 186, *c*), as is the case in Spiders; and lastly, they may be composed of two long styles which are capable of alternate movements backwards and forwards, whereby they can perforate foreign substances, much in the same manner as the saw of the *Tenthredo* among insects. The first of these forms are never provided with any poison-apparatus, and are only adapted to tear and pull to pieces alimentary substances; but in the second form poison-glands are superadded to the curved fangs, which, as in the proper Arachnidans, thus become formidable weapons.

(940.) The arrangement of the digestive apparatus in the Acaridans is one of the most interesting points in the economy of these creatures. Behind the mouth, M. Dujardin† was able to detect, in *Trombidium* and *Limnochares*, a cylindrical pharynx, with distinct parietes, into which are implanted numerous muscular fibres calculated to assist in the operation of suction by dilating the pharyngeal cavity; but posterior to this no traces are perceptible of either œsophagus, stomach, or intestine, so that, apparently, the juices of organized bodies, which constitute the sole food of these creatures, must be lodged in lacunary spaces, destitute of any proper walls, in the middle of a brown parenchymatous mass, which probably performs the functions of the liver. The lacunæ, into which nourishment is thus received, must necessarily be prolonged amongst the tissues and in the interspaces between the muscular fasciculi throughout the entire body, thus replacing altogether the circulating fluid; and even when living specimens of such genera (*Derma-*

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* Ann. des Sci. Nat. 1834.

† Id. 1845, t. iii. p. 14.

nyssus, Gamasus, Bdella) as are sufficiently transparent are submitted to examination under the microscope, although it is easy to see that the blood or other nutritive juices upon which the creatures live, and with which their bodies are filled, occupies a lobed or symmetrically multifid space, there is no appearance of any canal possessing distinct walls, but the whole seems diffused through lacunæ that extend even into the bases of the legs.

(941.) The *Acari*, however, possess an anal orifice, through which excrementitious matter undoubtedly issues; nevertheless, on examining this excrementitious substance, it appears rather to present the characters of a secretion, as, for example, in the case of the genus *Uropoda*, where it becomes consolidated on exposure to the air into a little horny stem, upon which the creature is attached as upon a pedicle. It might therefore, as M. Dujardin observes, be possible to conceive this kind of digestion in a mass acting much in the same way as the glands upon the nutritive juices submitted to their action.

(942.) In the most simply organized Acaridans, such as *Acarus* and *Sarcoptes*, no traces of any respiratory apparatus are discoverable, and respiration seems to be entirely effected by the general surface of the body. In *Ixodes, Gamasus*, and other Acaridans furnished with forcipated mandibles, on the contrary, numerous elegantly-ramified tracheæ, of which the larger trunks are distinguishable by a spiral filament, resembling that exhibited by the tracheæ of Insects, are dispersed through the body. These respiratory tracheæ communicate externally through the medium of minute stigmata, which in *Oribates* are situated between the first two pairs of legs.

(943.) Between these two extremes in the development of the respiratory system of the Acaridans, numerous intermediate grades exist in different genera; and, in some, M. Dujardin* has pointed out a mixed kind of respiratory process very different from anything as yet observed among articulated animals; this consists in a system of tracheæ terminating at a respiratory mouth situated at the base of the mandibles, and serving only for expiration, while inspiration is effected by the general integument and its appendages.

(944.) To render intelligible this phenomenon, it will be necessary to lay before the reader the description given by M. Dujardin of the respiratory (or, rather, expiratory) apparatus as it exists in *Trombidium*. It is as follows:—At the base of the mandibles superiorly is seen an oblong orifice, bounded by two lips, the structure of which is altogether remarkable: it is a perforated eminence (*bourrelet réticulé à jour*), the internal cavity of which communicates with two large tracheal vessels which run parallel to each other from behind forwards to this orifice. Each of the tracheal trunks, at a little distance from the orifice, suddenly divides itself into a tuft of tubular tracheæ, which are without any internal spiral filament, and which are distributed without any ramifications throughout all parts of the body. On observing a living Trombidium, it is seen frequently to agitate its mandibles as though to produce some movement of the air contained in the respiratory apparatus, and if at the same time a little water be placed upon the respiratory orifice, it is sometimes seen to become inflated with little bubbles of air.

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* *Loc. cit.* p. 17.

(945.) On dissecting a Trombidium, there is seen beneath the integument, which is covered with plumose hairs, an elegant network, made of a diaphanous substance of homogeneous appearance, which appears to be in relation with the plumose appendages of the integument, and in concert with them serves to absorb the gaseous elements that are subsequently emitted externally through the tracheal orifices.

(946.) In *Hydrachna* and the aquatic Acaridans, the expiratory system is similar to that which exists in *Trombidium*, only that, instead of plumose hairs upon the surface of the body, there are stomata something resembling those of plants—that is to say, apertures covered over with a very delicate membrane, beneath which is a subcutaneous network, such as exists in the terrestrial species.

(947.) The nervous system in *Trombidium*, and probably of the other Acari, presents a very remarkable arrangement, consisting entirely of a single large globular ganglion, from which nervous filaments are given off, both before and behind. The researches both of Treviranus and M. Dujardin deny the existence of anything like a supra-œsophageal ganglion or nervous collar around the œsophagus.

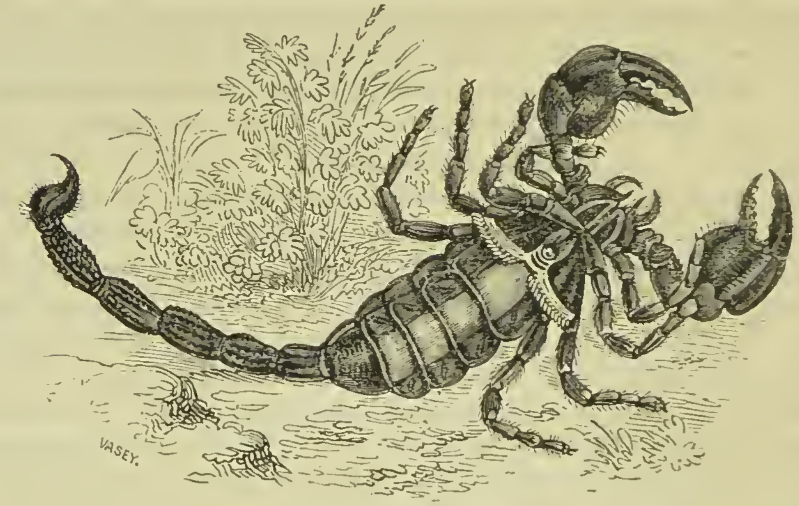
(948.) The eyes of the Acaridans are generally four in number, sessile, and approximated together in pairs upon the dorsal surface of the cephalothorax. In some cases, however, the eye is solitary, and composed of eight or ten minute facets.

(949.) *Trombidium* is the only Acaridan in which either M. Dujardin or Treviranus could discover the presence of a tubular two-branched ovarium; generally speaking, throughout this order of Arachnidans, the ova are produced in the substance of the general tissue of the body, without the presence of any ovarian apparatus with distinct parietes being apparent. The genus *Oribates* produces living embryos covered with a soft and wrinkled integument, which, as its development advances, becomes hard and crustaceous; in these Acari, therefore, in order to enable them to bring forth their young, it is necessary that the orifice of the vulva shall be of extraordinary dimensions; and accordingly it is found to be, in species thus constituted, a large oval orifice, occupying one-third or one-fourth of the entire length of the body, the opening being closed by two valves. In front of this large orifice, which is placed posteriorly, is another round opening, likewise terminated by valves, which gives issue to a long membranous tube, folded longitudinally and furnished with retractor muscles. It would appear possible, therefore, that this is a penis, and that *Oribates* is hermaphrodite; for, seeing that the young are born alive, it cannot be looked upon as an ovipositor, or as furnishing any secreted defence for the ova.

(950.) In conclusion, it seems evident, from the above-recorded circumstances connected with the organization of the Acaridan Arachnidans, that much of their history is as yet involved in great obscurity; sufficient, however, has been said to show that much interest is attached to many points in the economy of these minute creatures.

(951.) The rest of the Arachnidans breathe by means of lungs, or, as they are more properly designated, *pulmonary branchiæ*, and consequently, in contradistinction to the last-mentioned, are called by zoologists Arachnida Pulmonaria; such are the *Scorpions* and *Spiders*.

Fig. 184.



Scorpion (ventral aspect).

(952.) The Pedipalpi, forming the second division, are at once recognized by the peculiarity of their external configuration. Their palpi (the representatives apparently of the maxillary palpi of Insects) are exceedingly strong, and furnished at their extremity with a prehensile forceps; the hinder part of the body, corresponding with the abdomen of Insects, is much prolonged, and composed of numerous articulated segments, terminated in the Scorpion tribe by a sharp unciform sting (fig. 184) armed with a venomous secretion.

(953.) The third section embraces the Araneidæ, or *Spiders*, distinguished by having the abdomen short and globular, and furnished, moreover, near its posterior termination with *spinnerets*, by means of which these animals manufacture silken filaments applicable to a great number of purposes, and especially employed in constructing what is usually named the spider's *web*. The maxillary palpi in the females are simple, and more or less resemble feet; but in the males they often form a remarkable apparatus, to be described in another place. The jaws are also armed with sharp and hooked fangs, and perforated near their points for the emission of a poisonous secretion provided for the destruction of their prey, the venomous properties of which emulate that of the most formidable Serpents, and in like manner speedily terminate the sufferings of the victim.

(954.) Beginning with the first division, we shall now proceed to place before the reader such facts as have been ascertained, connected with the anatomical structure of the class under consideration. In the *Acaridæ*, or Mites, the skin of the entire body is so soft, that any annulose structure is scarcely distinguishable; the division, however, into *cephalothorax* and *abdomen* is sufficiently evident. The eyes are minute black points, never exceeding four in number, and resembling the *ocelli* of insects. Eight feeble legs are articulated with the thorax, properly so called. The mouth seems adapted to suction; and the jaws form a piercing instrument barbed at the extremity. The structure of the respiratory stigmata or spiracles would seem to differ very considerably from those of insects. According to Audouin, in the species which he examined (*Ixodes Erinacei**), each spiracle resembles a spherical tubercle perforated by an infinite number of small holes, in the centre of which may be remarked a larger circular plate; and it is through these numerous foramina that the air enters the body and gets into the tracheæ.

(955.) The Pulmonary Arachnidans, both of the pedipalp and spinning divisions, are strictly carnivorous in their habits, living upon the juices of the insects they destroy; and we may consequently expect, in the construction of their alimentary apparatus, a simplicity proportioned to the facility with which highly nutritive food composed of already-animalized materials is capable of being assimilated. The mouth varies somewhat in its conformation; and if we compare the pieces composing it with those we have found mandibulate insects to possess, we shall have good reason for surprise in noticing tho strange uses to which some parts of the oral apparatus are converted. In Scorpions (fig. 184), the apparent representatives of tho *mandibles* of an insect aro transformed into a pair of small forceps, each being provided with a moveable claw; these, therefore, of themselves form prehensilo organs adapted to seize prey and hold it in contact with tho mouth. But it is in tho *maxillæ* that we find the most extraordinary metamorphosis; for tho maxillary palpi, so small in insects, are found to be developed to such prodigious dimensions, that they far surpass in size and strength any of the ambulatory extremities, and, from their resemblance to the claws of Crustaceans, have given the character from which the name of the division is derived†. Each of these formidable organs is terminated by a strong pair of pincers, and thus the maxillary palpi become converted into potent instruments either for attack or defence. The representative of the *labium* of an insect, in the Arachnidans, has no palpi connected with it.

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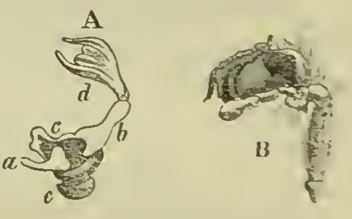
* Cyclop. of Anat. and Phys., art. "ARACHNIDA."

† *Pes*, a foot; *palpus*, a feeler.

(956.) In Spiders, the organization of the mouth is altogether different. The mandibles (fig. 186, *o o*) are each terminated with a moveable fang (*c*), which ends in a sharp point, and is perforated near its extremity by a minute orifice, from which, when the Spider bites, a venomous fluid of great potency is instilled into the wound inflicted; such, indeed, is the malignity of this poisonous secretion that its effects in destroying the life of a wounded insect are almost instantaneous, and in some of the large American species even small birds fall victims to its virulence. The organ in which the poison is elaborated is represented in the figure above referred to; it is a long and slender bag, from which an attenuated duct may be traced through the body of the mandible as far as the perforated extremity of the fang.

(957.) The palpi connected with the maxillæ of the Spider are terminated in the female by a simple hook; but in the males of many species they exhibit a conformation slightly resembling the forceps of the Scorpion, although provided for a very different purpose. When closed (fig. 185, B), the terminal part of the palpus presents a club-like dilatation, which, however, on close inspection will be found to consist of several pieces (fig. 185, A, *a*, *b*, *c*, *d*, *e*), connected with each other by articulations, and capable of being opened out in the manner represented in the figure. This strange instrument was formerly imagined to be the penis of the male Spider, and was thought to contain the terminations of the seminal ducts: this supposition, however, has been proved to be erroneous; for the palpus is imperforate, and the sexual apertures of the male are situated elsewhere; but the organ in question is nevertheless apparently used in the process of impregnation, in a manner to be explained hereafter.

Fig. 185.

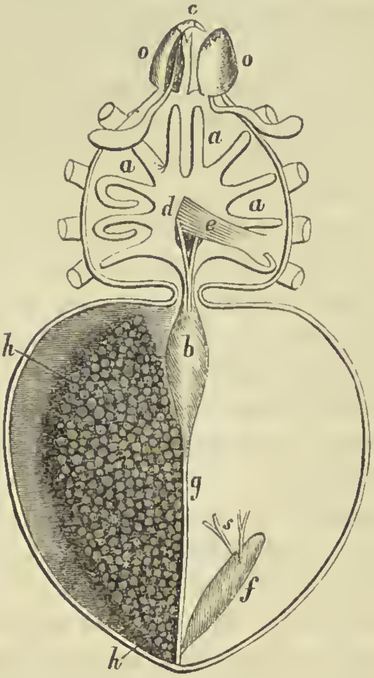


Palpus of male Spider.

(958.) Both in Scorpions and Spiders the alimentary canal is exceedingly narrow, presenting scarcely any of those dilatations met with in the digestive organs of insects. This is a natural consequence of the nature of their food; for as they live entirely upon animal juices sucked from the bodies of their victims, there could be little necessity for the presence of capacious receptacles for nutritious matter, or for any reservoirs for the accumulation of effete material.

(959.) In the Scorpionidæ there is no stomachal dilatation whatever: a straight intestine passes directly from the mouth to the anus, situated at the extremity of the abdomen; and the insertion of the biliary vessels forms the only distinction between its ventricular and intestinal divisions. Five delicate cæca are derived from each side of the ventricular portion, and plunge into the centre of a fatty substance in which the alimentary canal is imbedded. In Spiders, likewise, cæca are appended to the commencement of the digestive apparatus; and a slight enlargement (fig. 186, *b*) may be said to represent the stomach, from which a slender intestine (*g*) is continued to the anus. As in the Scorpion, a large quantity of fat (*h*) surrounds the nutrient organs and fills up a great proportion of the cavity of the abdomen. Like the fat-mass of the larvæ of insects, this substance must, no doubt, be regarded as a reservoir of nutriment; and when the habits of these animals are considered, the precarious supply of food, and the frequent necessity for long-protracted fasts when a scarcity of insects deprives them of their accustomed prey, such a provision is evidently essential to their preservation.

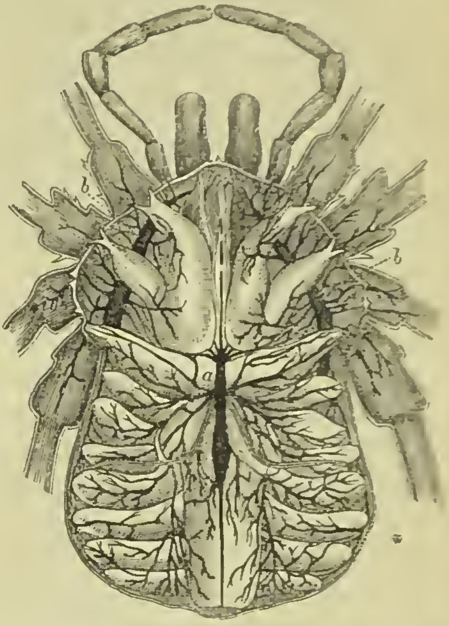
Fig. 186.



Digestive system of the Common Spider: *c*, poison-fang; *o o*, the jaws, with their appended poison-glands; *a a a*, cæcal appendages to *d*, the commencement of the alimentary canal, with which the muscle (*e*) is connected; *b*, stomachal dilatation; *g*, intestine; *h h*, accumulation of fat; *f*, sacculus receiving the terminations of the secreting-tubes (*s*).

(960.) One peculiarity connected with the arrangement of the chylopoietic viscera of the Spider is the manner in which the biliary organs terminate in the intestine; for instead of entering in the usual position, namely close to the termination of the stomach, they seem to pour their secretion into the rectum, immediately in the vicinity of the anus. At this point, a kind of sacculus (figs. 186 & 188, *f*) joins the intestine, into which the branched tubes (fig. 188, *o o*, & fig. 186, *s*) empty themselves. This circumstance has long been a subject of interesting inquiry to the comparative physiologist. If the fluid secreted by these tubes be really bile, in what manner does it accomplish those purposes usually supposed to be effected by the biliary secretion? It would seem to be, in this case, merely an excrementitious production. Are the cæca appended to the stomach biliary organs? If so, the apparatus in question may be of a totally distinct character, and its product only furnished to be expelled from the system. In conformity with the last supposition, many anatomists have been induced to regard these vessels as being analogous to the urinary secernents of more highly organized animals, and have not scrupled to apply to them the appellation of *renal vessels*: but this hasty application of names we have already animadverted upon as being highly prejudicial to the interests of science; and in this instance, as in many others, to wait for the results of future investigations is far more advisable than rashly to assign a definite function to a part the real nature of which is a matter of speculation.

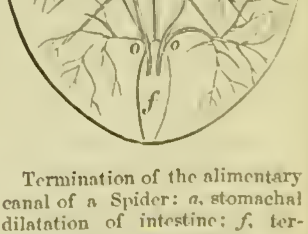
Fig. 187.



Digestive and circulatory apparatus of the Harvest Spider: *a*, the stomach, with its lateral cæca, on which is situated the dorsal vessel; *b b*, vascular sinuses.

(961.) The respiratory system of the Pulmonary Arachnidans is constructed upon very peculiar principles, being neither composed of gills adapted to breathe water, nor of lungs like those of other air-breathing animals, but presenting a combination of the characters of both. The *pulmonibranchiæ* are, in fact, hollow viscera resembling bags, the walls of which are so folded and arranged in laminæ, that a considerable surface is presented to the influence of oxygen. It is, indeed, highly probable that these organs are intermediate in function as well as in structure between an aquatic and air-breathing respiratory apparatus; for, as both the pedipalp and spinning Arachnidans frequent moist situations, the dampness of the atmosphere may be favourable to the due action of the air upon the circulating fluids of these creatures. Each *pulmonibranchia* opens externally by a distinct orifice resembling the spiracle of an insect, and is closed in a similar manner by moveable horny lips. In the Scorpion (fig. 184) the spiracles are eight in number, placed upon the ventral aspect of the body; and just in front of the first pair of breathing-holes are two remarkable organs (represented in the figure), resembling a pair of combs, which are apparently adapted to keep the spiracular

Fig. 188.



Termination of the alimentary canal of a Spider: *a*, stomachal dilatation of intestine; *f*, terminal sacculus receiving the terminations of the secerning vessels (*o o*).

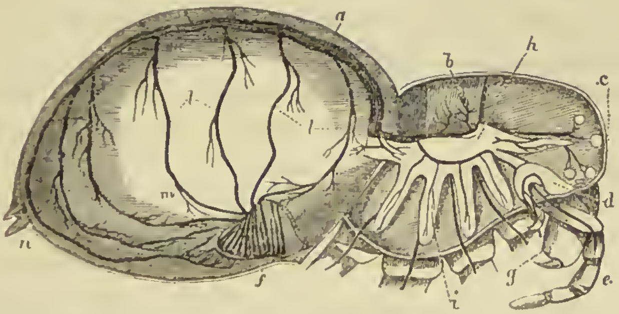
orifices free from dirt, and thus prevent any obstruction to the free ingress and egress of the air.

(962.) In the Araneidæ, the form and arrangement of the spiracles are somewhat different. According to Treviranus, there are four pairs on each side of the cephalothorax, situated immediately above the insertions of the legs; and in addition to these, there is one pair constantly found on the under surface of the abdomen, and four pairs of smaller apertures of less importance on its upper part.

(963.) In order to understand the manner in which respiration takes place in *pulmonibranchiæ* of the structure above described, it is necessary to suppose the existence of a vascular apparatus, by means of which the circulating fluid is continually spread over the laminæ of the respiratory sacculi, and afterwards returned to the circulation in a purified condition. It is true that, owing to the extreme difficulty of tracing vessels of such small dimensions, the continuity of the entire system is rather an inference deducible from a general review of the facts ascertained, than absolutely a matter of demonstration. We will therefore briefly lay before the reader the data upon which physiologists found the opinions entertained at the present day relative to the means whereby the circulation of Arachnidans is accomplished.

(964.) According to Treviranus, spiders are provided with a long contractile vessel (fig. 189, *a*), which runs along the mesial line of the back, and resembles in form the dorsal vessel of insects, although in structure it is widely different. In insects, it will be remembered, the dorsal vessel communicated freely with the abdominal cavity by numerous valvular apertures, and neither arteries nor veins were necessary for diffusing the blood through the system; but in the Pulmonibranchiate Arachnidans numerous vascular trunks (*l l*) are given off from both sides of the dorsal heart and are dispersed in all directions. All the branches proceeding from the sides of the dorsal vessel are presumed to be of an arterial character, with the exception of a few large canals

Fig. 189.



Plan illustrating the circulatory system in a Spider: *a*, dorsal vessel; *b*, suspensory muscle; *c*, the ocelli; *d*, poison-gland; *e*, palpus; *f*, pulmonibranchial organ; *g*, poison-fang; *h*, cephalothorax; *i*, cæcal appendices to the stomach; *l*, vascular trunks derived from the dorsal heart, running to the pulmonibranchiæ; *m*, abdomen; *n*, spinnerets.

situated near the junction of the anterior and middle thirds of its length, and these are supposed to be veins* (*branchio-cardiac vessels*) destined to return the aërated blood from the *pulmonibranchiæ* (*f*) into the general circulation. Whoever watches the movements of the blood in one of the limbs of these creatures will perceive that, under the microscope, its motion bears little resemblance to that observable in the foot of a frog, or in animals possessed of an arterial and venous system completely developed. So irregular, indeed, is the course of the globules, that it would be difficult to conceive them to be confined in vessels at all; the whole appearance resembles rather the diffused circulation seen in the larva of an insect, than that of a creature possessing vascular canals arranged in definite directions. The only probable way of accounting for such a phenomenon is by supposing that, in this first sketch of a vascular system, if we may be pardoned the expression, the veins are mere sinuses or wide cavities formed in the interstices of the muscles, through which the blood slowly finds a passage. From a review of the above-mentioned facts we are at liberty to deduce the following conclusions relative to the circulation of Arachnidans:—The *pulmonibranchiæ* being apparently the only organs of respiration, the blood must be perpetually brought to these structures from all parts of the system, to receive the influences of oxygen, and again distributed through the body. Such a circulation could only be accomplished in circumscribed channels—some destined to propel it through all parts, others to collect it after its distribution and bring it to the respiratory organs, and a third set to return it in a renovated condition to the heart. The circuit of the blood may therefore be presumed to be completed in one or other of the following modes:—The dorsal vessel, or heart, by its contraction drives the blood through numerous arterial canals to the periphery of the system; the blood so distributed gradually finds its way into capacious sinuses, through which it flows to the branchial organs, and from hence it re-enters the heart by the *branchio-cardiac* vessels above referred to: or else the action of the heart drives a portion of the circulating fluid into the *pulmonibranchiæ* by the same effort which supplies the rest of the system, and the blood so impelled to the respiratory organs becomes, after being purified, again mixed up with the contents of the veins which return it to the heart.

(965.) In the Scorpions, the circulatory system resembles that of the Myriapoda, but it is more completely organized; the heart, which, as in the Scolopendra, is divided into compartments, is elongated at its posterior extremity into a long caudal artery, and gives off from each chamber a pair of systemic arteries, which are distributed among the viscera, and also send their principal divisions to supply the muscles of the inferior and lateral regions of the body, as well as the pulmonary sacs. At the anterior part of the abdomen, the heart assumes the character of an

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* Audouin, Cyclop. of Anat. and Phys., art. "ARACHNIDA."

aorta, descending suddenly into the thorax, and dividing immediately behind the brain into a number of large vessels, that supply the head and the locomotive organs. The posterior of these form a vascular collar around the œsophagus, which gives origin to the great arterial trunk, or supra-ganglionic vessel, whereby the blood is conveyed to the posterior part of the body, as in the Myriapoda (*vide* § 746). This vessel passes beneath the transverse arch of the thorax, with which it is slightly connected by fibrous tissue, and then runs backwards, gradually diminishing in size, until it reaches the terminal ganglia of the tail, where it divides into branches that accompany the nerves. In addition to the above arrangement, Mr. Newport has discovered a fibrous structure, from which are given off two pairs of vessels, to be distributed to the first pair of branchial organs, as also a little vessel which, passing backwards, anastomoses with the spinal artery, to form the sub-spinal vessel. This latter takes its course beneath the chain of nervous ganglia, communicates directly by means of short branches with the supra-ganglionic artery, and, at intervals, gives off from its under surface large vessels, which, uniting together, convey the blood which has circulated in the abdominal segments directly to the branchiæ, whence it is returned to the heart by a great number of slender canals, which, emanating from the posterior aspect of each branchial organ, unite to form larger trunks, that run along the walls of the segments, to pour their contents into the valvular orifices situated upon the dorsal aspect of the heart.

(966.) The heart of the Scorpion* is a strong muscular organ extending along the middle of the back, from its continuation with the great caudal artery in the last segment of the abdomen to the commencement of the aorta. In the dorsal part of its course the heart is divided into eight separate chambers, which are wider and stronger in proportion to their length than in the highest of the Myriapoda. They are more muscular and compact in proportion to the greater quantity of blood to be transmitted through them, and the force with which it is necessarily propelled. The form of each chamber is somewhat heart-shaped, being slightly contracted in its middle portion and enlarged at its posterior. Each chamber has two auricular openings for the passage of the blood, placed very close to the median line of the heart on its dorsal surface; and it gives off at its inferior lateral angles a pair of large arterial vessels (the systemic arteries), which distribute the blood downwards to the viscera and to the dorsal and lateral surfaces of the body.

(967.) Each chamber is provided at its sides, as in the Myriapoda and Insects, with two sets of muscles, the *alæ cordis.* The anterior and larger pair of muscles are attached to the anterior part of each segment, and pass diagonally forwards, and the posterior (the proper retractor muscles of the chamber) to its posterior angle, and pass backwards, leaving between the two sets of muscles a passage for the vessels.

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* Newport, Phil. Trans. 1843.

(968.) The structure of the chambers internally differs considerably from that of the chambers in the Melolontha, as described by Straus-Durckheim (§ 852). Each valve, or division between them, is formed by a reduplication of the whole muscular structure of the dorsal surface of the organ. This reduplication, which is chiefly on the upper and lateral surfaces, is very imperfect on the under, and in some of the chambers is entirely absent on the under surface. The reason for this imperfect structure of the valves may perhaps be explained by the fact that the blood is distributed from the heart, in the Scorpion, in opposite directions—partly backwards towards the tail, but chiefly forwards towards the head and sides; and hence it may be necessary that a reflux of the blood should not be entirely prevented, as may be required in those instances in which the whole current is in one direction. The structure of the heart is exceedingly thick, opake, and muscular; it is formed of two layers of fibres, longitudinal and circular in each layer, the most powerful of which are the latter. On its internal surface it is smooth, and lined by an exceedingly delicate membrane, through which the strong circular fibres are distinctly marked. It is by means of these that its most powerful contractions are effected,—the auricular action being chiefly the result of the relaxation of these fibres, assisted by the reactions of the lateral muscles.

(969.) The aorta arises from the anterior extremity of the heart or dorsal vessel. It is short, thick, and smooth on its external surface, without lateral muscles or internal divisions into chambers. It descends obliquely forwards and downwards, and after passing beyond the great median arch of the thorax, to which many of the muscles of this region of the body are attached, it gives off the vessels to the head, to the organs of locomotion, and to form the great supra-spinal artery, which, as in the Myriapoda, represents the aortic trunk, or rather the *aorta descendens*, which, running above the chain of nervous ganglia, supplies the neighbouring parts in this region of the body, as well as branches to the alimentary canal and to the liver.

(970.) *The portal system of vessels* is situated chiefly below the nervous cord, on the ventral surface of the body, and is the means by which the blood is collected and conveyed to the branchiæ, from which it seems to be returned to the system, after circulating through the organs, by means of a large sinus or vessel at their posterior superior angles. Behind the bony arch of the thorax there is a hollow fibrous structure, that closely surrounds the cord and nerves as in a sheath. It seems to form a kind of sinus, from the posterior part of which a small vessel passes backwards, which, joined by anastomoses from the supra-spinal artery, forms the commencement of the sub-spinal vessel; and it gives off two pairs of vessels at its sides. The first and second pairs of these efferent vessels, covered by the thick peritoneal lining of the abdomen, send the blood in a diagonal direction backwards to the first pair of abdominal branchiæ. The first pair of these vessels originate close to the folds of the diaphragm. They pass backwards and outwards into the abdomen, and are joined in their course by numerous small vessels from the sides of the segments, and immediately anterior to the first pair of abdominal branchiæ are each divided into two branches, which are again divided and subdivided into a multitude of anastomosing vessels before they are distributed on tho branchiæ. These branchiæ likewise receive the second pair of efferent vessels, which, like the first, pass diagonally backwards from the fibrous structure to the inner side of the branchiæ, on approaching which they are divided like the other pair into two branches, which are subdivided, and anastomose with the divisions of the first pair. The whole form a most intricate web of anastomosing pulmonic capillary vessels before they are distributed on the anterior part of the branchiæ. We have thus a complete distribution of the blood to the pulmonibranchiæ in the anterior part of the abdomen. There is a similar but less perfect distribution in the posterior.

(971.) Professor Müller* has accurately described the pulmonibranchiæ as formed of a multitude of closely-approximated, thin, double lamellæ, which communicate, by a small orifice in each, with the external air admitted into a common cavity through the spiracle on the surface of the body. The blood, distributed through these lamellæ, is brought into contact with the air in their interior through their membranous structure. The minute anatomy of these lamellæ, and the manner in which they are permeated by the blood, afford some points of interest. Each side of these double lamellæ is formed of an exceedingly delicate and apparently structureless double membrane, which includes within it a parenchymatous tissue formed of single vesicles or cells. The convex margin of each lamella is bounded by a delicate but distinct vessel, which seems to form the means of intercommunication with the anastomosing network of vessels distributed over the branchiæ, since the delicate evanescent vessels traced into tho lamellæ are derived from those which bound their convex margin.

(972.) At the posterior part of the inner side of tho branchiæ, where the lamellæ are covered by the thick membrane and peritoneum that lines the common cavity of the branchiæ, there are several small orifices, the commencement of vessels which afterwards, when collected together, form the larger channels that convey back the blood to the heart. These vessels form delicate trunks or sinuses, which pass around the sides of the body in the posterior part of each segment, and, becoming gradually enlarged by communicating with other vessels in their progress, pour their contents into the heart at the auricular orifices upon its dorsal aspect.

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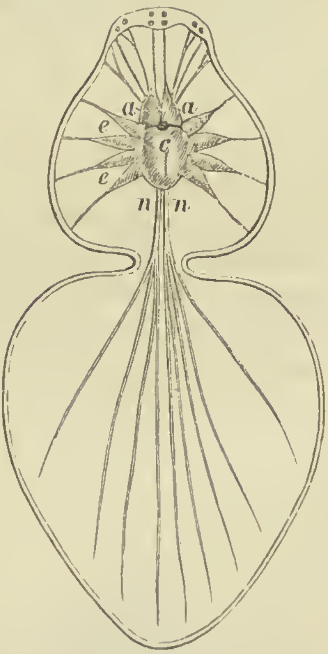
* Meckel's Archiv, 1828.

(973.) The following, then, will be the course of the circulation in the Macrourous Arachnidans. The blood received by the veins from the branchiæ is conveyed to the heart round the sides of the segments, receiving accessions from other vessels in the segments in its course, and enters the heart at the posterior part of each chamber through the orifices of Straus-Durckheim. The auriculo-ventricular cavity, dilated by the influx of blood, begins first to contract by the action of the circular fibres at the posterior part of each chamber. By this contraction, part of the blood is at once propelled laterally, through the systemic arteries, to the interior and sides of the body, while the remaining and chief portion is forced onwards, through the valves and body of the chamber, by the successive contraction of the circular fibres, into the next chamber. A fresh accession of blood enters the heart at the auricular orifices in the short interval of time that elapses between the contractile actions of the two chambers, which interval is probably occasioned by the reaction of the lateral muscular appendages of the organ. These contractions are carried gradually onwards through the whole of the succeeding segments; so that before a third chamber has contracted, the first is again filled and ready to be emptied, thus occasioning, by their alternate movements, those pulsatory motions which are so well known in the dorsal vessel of Insects. The blood, propelled by these successive contractions through the aorta, is distributed to the organs in the head and thorax and the organs of locomotion. Part of it is also sent round the aortic arches through the supra-spinal artery backwards into the abdomen, giving off its minute currents for the nourishment of the nervous ganglionic cord, while another portion, intermingled with that collected in the portal vessels, is sent to the branchiæ. But its principal current still flows in the supra-spinal artery, along the upper surface of the cord to the terminal ganglion of the tail, where it divides into four streams, two of which go out at the sides of the ganglion to nourish the segment, while the other two, now greatly reduced in size, proceed backwards along the terminal nerves of the cord, and, becoming more and more subdivided in the last segment of the tail, are diffused through the surrounding structures. These form minute anastomoses with numerous small vessels, which, gradually collecting in separate trunks on the under surface of the last segment, form the origin of the caudal portion of the sub-spinal vessel which conveys the returning blood forwards from the tail to the abdomen, to be aërated in the branchiæ before it is again transmitted to the heart. In like manner, the blood that has already circulated through the organs of locomotion, the cephalothorax, and abdomen, appears to be collected in the veins which transmit it to the branchiæ before it is again employed in the circulation. Throughout the whole of its course along the artery in the tail, the blood is passed in small currents into the sub-spinal vessel,—thus intermingling the venous and arterial blood, precisely as occurs in tho abdomen. But the circulation in the caudal prolongation of the heart yet remains to be explained. We have already seen that the great dorsal artery in the tail, above the colon, forms direct vascular communications around its sides with the sub-spinal vessel upon the ventral surface, in which the course of the blood is propelled forwards to the abdomen. It is certain, therefore, that the action of the great chamber of the heart must impel the blood at once in every direction, chiefly forwards, and laterally, but also in part *backwards* through the caudal artery; otherwise it would be impossible for this structure to form its anastomoses with the sub-spinal vein without occasioning two opposing currents in the same vessel.

(974.) In the nervous system of Spiders we observe that progressive concentration of the nervous centres, which we have traced through the lower forms of the Homogangliata, carried to the utmost extent. Spiders are appointed destroyers of insects, with which they maintain cruel and unremitting warfare. That the destroyer should be more powerful than the victim is essential to its position; that it should excel its prey in cunning and sagacity is likewise a necessary consequence; and by following out the same principles which have already been so often insisted upon, concerning the inseparable connexion that exists between the perfection of an animal and the centralization of its nervous ganglia, we find in the class before us an additional confirmation of this law. In Scorpions, indeed, the nervous masses composing the ventral chain of ganglia are still widely separated, especially those situated in the segments of the tail: in the cephalothorax they are of proportionately larger dimensions, and moreover exhibit this remarkable peculiarity, that, instead of being united by two cords of communication, there are three interganglionic nerves connecting each division. It is in Spiders that the concentration of tho nervous system reaches its climax; for in them we find tho whole series of ganglia (encephalic, thoracic, and abdominal) aggregated together, and fused, as it were, into one great central brain, from whence nerves radiate to all

Fig. 190.



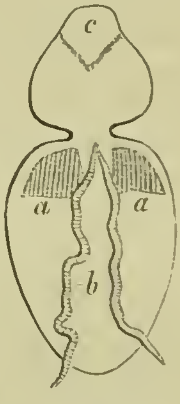
Nervous system of the Spider: *a a*, encephalic ganglia, from which are derived the optic nerves; *e e*, thoracic ganglia, forming by their coalescence the central mass (*c*); *n n*, nerves supplying the abdomen.

parts of the body. The extent to which centralization is here carried will be at once appreciated by reference to the annexed figure (fig. 190): the encephalic masses (*a a*), whence the optic nerves distributed to the ocelli are derived, are in close contact with the anterior part of a large ganglion (*c*), that represents all the abdominal ganglia collected into one mass; and from the posterior part of this, nerves (*n n*), destined to supply the parts contained in the abdomen, derive their origin. The thoracic ganglia (*e e*) are fusiform, and placed on each side of the mass (*c*), with which they are apparently amalgamated at one extremity, while from the opposite they give off the nerves appropriated to the legs.

(975.) The ocelli or eyes of Arachnidans have been minutely investigated by Müller*, and seem to present a type of structure very far superior to that of insects. In the Scorpion, this distinguished anatomist succeeded in detecting most of the parts which enter into the construction of the eye of a vertebrate animal, and, moreover, a great similarity in their arrangement. The cornea, a globular lens, the aqueous and vitreous humours, the retina and choroid, were all found nearly in their usual relative positions; so that the sense of vision in these animals must be extremely perfect.

(976.) The sexual organs of the male and female Arachnidans exhibit very great simplicity in their structure. The testes, or secreting vessels, of the male Spider are two long cæca (fig. 191, *b*), lodged in the abdomen, and terminating by simple orifices at the ventral surface. No external intromittent organ is perceptible; and it was on this account that the peculiar apparatus above referred to, situated at the extremity of the maxillary palpus, was so long considered as giving passage to the impregnating secretion. The singular instrument already described (§ 957) would seem, indeed, to be in some manner really subservient to the fecundating process, being used most probably as an exciting agent preparatory to the intercourse between the sexes.

Fig. 191.



Generative organs of male Spider: *a a*, pulmonibranchiæ; *b*, testes; *c*, cephalothorax.

(977.) The ovigerous system of the female is equally devoid of complication, and, like the male testes, consists of two elongated membranous sacculi, in which the eggs are formed and brought to maturity. The impregnation of the ova is evidently effected by the simple juxtaposition of the external orifices of the two sexes: yet such is the ferocity of the female spider, that the accomplishment of this is by no means without risk to her paramour; for the former, being far superior to the male both in size and strength (fig. 192, A, B), would infallibly devour him, either before or after the consummation of his purpose, did he not exercise the most guarded caution and circumspection in making his advances.

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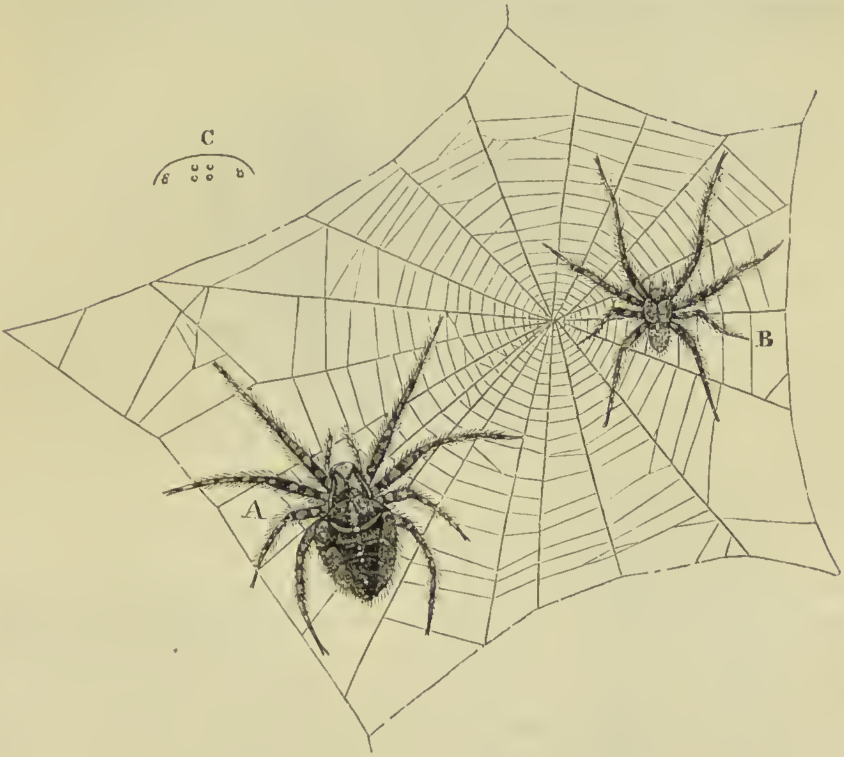
* Ann. des Sci. Nat. tom. xvii.

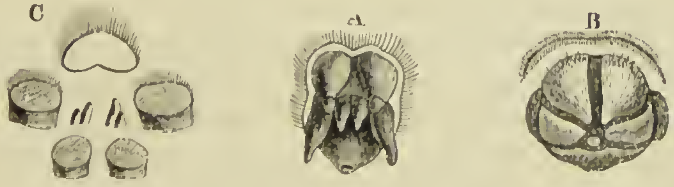
Fig. 192.



A. Female Spider. B. Male of the same species. C. Arrangement of the eyes.

(978.) One peculiar characteristic of the Araneidæ is the possession of a spinning apparatus, whereby the threads composing their web are manufactured. The instruments employed for this purpose are situated near the posterior extremity of the abdomen (fig. 194^a, *h*), and consist externally of four *spinnerets* and two palpiform organs (fig. 193, A, B). Each *spinneret*, when highly magnified, is found to be perforated at its extremity by innumerable orifices of extreme minuteness (fig. 193, C), through which the filaments are drawn; so that, unlike the silk of the Caterpillar, the thread of the Spider, delicate as it is, is composed of hundreds

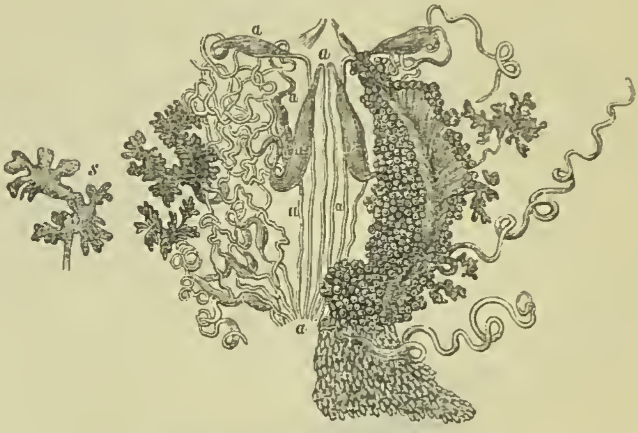
Fig. 193.



Spinning apparatus of the Spider.

of smaller cords, sometimes woven together by zigzag lines, and thus exhibiting a structure of exquisite and most elaborate composition. The fluid silk, which, when it is drawn through the microscopic apertures of the spinneret, affords the material whereof the web is constructed, is secreted in a set of glands represented in the subjoined engraving (fig. 194). The secerning extremities of the glandular tubes are composed of branched cæca (*s*), whence arise long and tortuous ducts (*a a a*), that become dilated in their course into reservoirs for the secreted fluid, and terminate by several canals at the base of the external spinning tubuli. Various are the purposes to which the different species of the Araneidæ convert the delicate threads thus produced. Some construct silken tubes or cells in which to conceal themselves from pursuit, and from this retreat they issue to hunt for prey in the vicinity of their abode; others strew their filaments about at random, apparently to entangle passing insects; many make nets composed of regular meshes, and spread them out in favourable situations to entrap their victims (fig. 192); while a few species, enveloping their eggs in bags of curious construction, carry them about attached to their bodies, and defend them with the utmost courage and pertinacity: even in water these webs are turned to many singular uses; and ropes, nets, and even diving-bells are at the disposal of aquatic species furnished with this extraordinary spinning machinery.

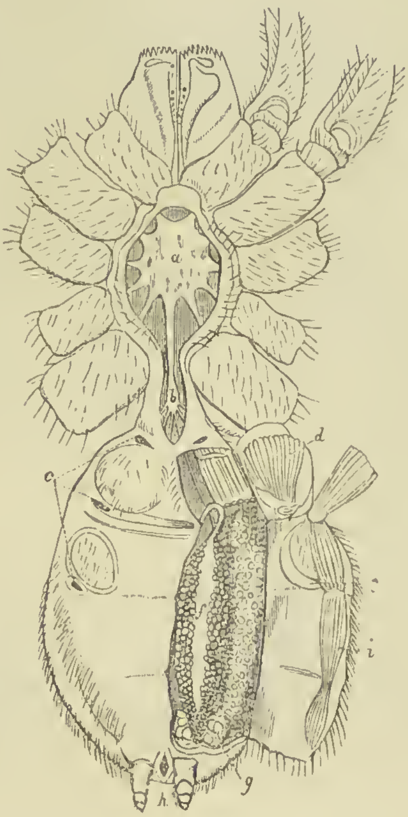
Fig. 194.



Silk-secreting glands of the Spider.

(979.) A few only of the most remarkable applications of this delicate material can be noticed in this place. The Mason-spiders (*Mygale*) excavate for themselves subterranean caverns, in which these marauders lurk secure from detection even by the most watchful foe; nor could any robber's den which ever existed in the wild regions of romance boast more sure concealment from pursuit, or immunity from observation. The construction of these singular abodes has long excited the admiration of the naturalist: a deep pit is first dug by the Spider, often to the depth of 1 or 2 feet, which, being carefully lined throughout with silken tapestry, affords a warm and ample lodging; the entrance to this excavation is carefully guarded by a lid or door, which moves upon a hinge, and accurately closes the mouth of the pit. In order to form the door in question, the Mygale first spins a web which exactly covers the mouth of the hole, but which is attached to the margin of the aperture by one point only of its circumference, this point, of course, forming the hinge. The Spider then proceeds to lay upon the web a thin layer of the soil collected in the neighbourhood of her dwelling, which she fastens with another layer of silk; layer after layer is thus laid on, until at length the door acquires sufficient strength and thickness: when perfected, the concealment afforded is complete; for as the outer layer of the lid is formed of earth precisely similar to that which surrounds the hole, the strictest search will scarcely reveal to the most practised eye the retreat so singularly defended.

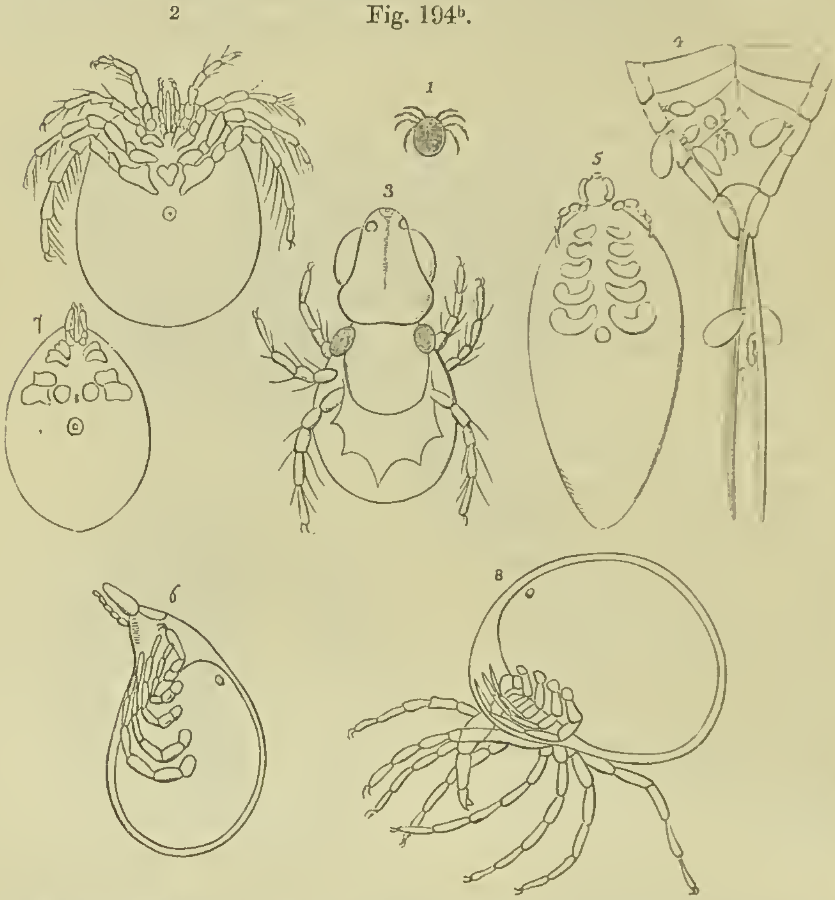
Fig. 194ᵃ.



Anatomy of *Mygale*: *a*, centralized ganglia of the nervous system; *b*, termination of the ganglionic cord; *c*, respiratory stigmata; *d*, anterior pulmonibranchial organ of the left side, displayed; *e*, posterior pulmonibranchial organ, partially covered by a large abdominal muscle (*i*); *f*, ovary; *g*, section of integument; *h*, spinnerets and anal aperture.

(980.) Another Spider (*Clotho Durandii*) constructs a dwelling equally artificial and ingenious—a kind of tent, in which it lives and rears its young. This tent is composed of several superposed sheets of the finest taffeta, and its contour presents seven or eight prominent angles, which are fixed to the surface of the ground by silken cords. The young Clotho at first lays down only two sheets thus secured, between which she hides herself; but, as she grows older, she continually lays down additional coverings, until the period when she begins to lay her eggs, at which time she constructs an apartment, soft, downy, and warm, specially devoted to their reception. The exterior sheet of the tent is purposely dirtied for the purpose of concealment; but, within, everything is beautifully clean and white. The most admirable part of the contrivance, however, is the perfect safety afforded to the young when the parent leaves her tent in search of food: some of the superposed sheets are fastened together at their edges; others are simply laid upon each other; and as the parent herself alone possesses the secret which enables her to raise those layers by which entrance is to be obtained, no other animal can find its way into her impenetrable abode.

Fig. 194^{b}.



1. Female of *Hydrachne globulus*, represented of the natural size just previous to oviposition. 2. The same magnified, and seen from below, showing the mouth or beak furnished with two palpi, and the eight legs appended to four separate pairs of coxæ; between the hinder pair may be seen the heart-shaped genital scale, and a little posterior to this a round orifice, which is the anus. 3. Newly-hatched larva of *Hydrachne globulus*. 4. Hinder part of an aquatic insect (*Nepa cinerea*), to which numerous nymphæ of *Hydrachne* in different stages of growth are attached. 5. One of these nymphs magnified, exhibiting the head-like sucker provided with a pair of palpi, immediately behind which are seen two of the epidermic cases of two of the old legs of the larva (the four others have fallen off), and posterior to these, five pairs of little sprouts, which are the rudiments of antennæ and legs: the median circle indicates the position of the genital organs. 6. Represents the same nymph in its last stage of development, seen in profile: the integuments are supposed to be transparent, so as to show the young *Hydrachne* within, ready to escape. 7. Ventral surface of young *Hydrachne*, showing the arrangement of the coxæ. 8. Secondary nymph making the transition from the second to the third phasis of the creature's existence: the perfect animal, ready for its escape, is represented encased in the integuments of the preceding, the epidermic sheaths of the limbs still remaining adherent to the exuvium.

(980^{a}.) The development and mode of exuviation of some of the Acaridans offer several very curious and interesting phenomena. The

Hydrachne, or Water-mites, for example, at their birth present themselves under the form represented in fig. 194^b, 3, being at that time provided with only six locomotive limbs and a very remarkable proboscis*. These larvæ at first swim at large in the water, but at length contrive to fix themselves to the body of some aquatic insect, in which position they pass into the state of nymphs (fig. 194^b, 4); the hinder part of their bodies becomes remarkably elongated, and at length assumes the form of a pear, in which all resemblance to its former state is lost. Nevertheless, during this remarkable increase in size, the proboscis and the legs undergo but little alteration; for as soon as the body begins to elongate, the legs and the palpi are withdrawn from their original integument, and, retiring with the body into the pear-shaped sac formed by the distended skin, nothing is left behind but the exuviated sheaths of the old legs, which are then easily broken off by the slightest violence. A nymph, formed in the interior of its own skin, has replaced the larva; but it is a nymph which continues to nourish itself, and to increase in size, until it assumes the appearance shown at fig. 194^b, 5, in which the rudiments of a new set of legs are clearly perceptible through the transparent envelope: the eyes of the contained animal are distinctly traceable, and may even be seen to abandon their former corneæ, and to recede in the same proportion as the limbs from the old case, which at last, rending transversely into two portions, allows the new animal to escape, which immediately begins to swim vivaciously about, under a form closely resembling that of the parent. It has, however, still another moult to go through before it can be pronounced adult; for, after having lived some weeks in this third condition, and visibly increased in size, these immature individuals fix themselves to some water-plant, to which they hold firmly by means of their beak and claws, and, becoming motionless, again exuviate (fig. 194^b, 8), and are ready to reproduce their kind.

CHAPTER XIV.

CRUSTACEA.

(981.) Insects and Arachnidans are air-breathing animals; and even in such species of these two extensive classes as inhabit fresh water, respiration is strictly aërial. No insects or spiders are marine; and consequently the waters of the ocean would be utterly untenanted by corresponding forms of Articulata, were there not a class of beings belonging to this great division of the animal world so organized as to be capable of respiring a watery medium, and thus adapted to a residence in the recesses of the deep. Examined on a large scale, the Crustaceans, upon the consideration of which we are now entering, are marine creatures: many species, it is true, are found abundantly in the lakes and ponds around us; but these form rather exceptions to the general rule; and we may fairly regard this extensive group of beings as the aquatic representatives of the Insects and Spiders, with which they form a collateral series.

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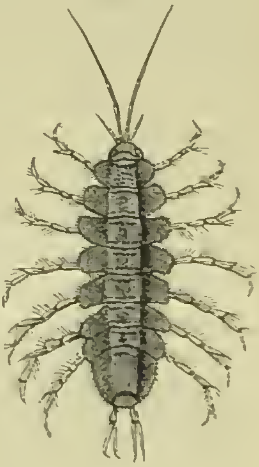
* Dugès, Ann. des Sci. Nat. 2 sér. tom. i. p. 165.

(982.) The tegumentary system of the CRUSTACEA corresponds in its essential structure with that of insects, and consists of a vascular dermis, a coloured pigment, and a cuticular secreted layer which forms the external shell or skeleton: the latter, or epidermic covering, however, differs materially in texture from that of other Articulata, inasmuch as it contains calcareous matter in considerable abundance, and thus acquires in the larger species great density and hardness.

(983.) As regards the mechanical arrangement of the skeleton, we shall find the same general laws in operation as we have observed throughout all the Annulose orders —a continual centralization and progressive coalescence of the different rings or elements composing the external integument, and a strict correspondence between the degree to which this consolidation is carried and the state of the nervous system within.

(984.) In the lowest forms of the Crustacea we have, in fact, a repetition of the condition of the skeleton met with in the Myriapoda, or in the larva state of many insects,—the whole body being composed of a series of similar segments, to which are appended external articulated members of the simplest construction (fig. 195).

Fig. 195.



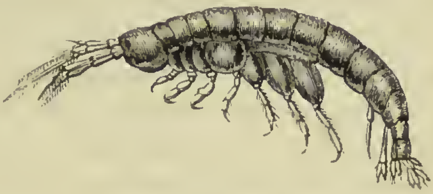
(985.) The number of rings or segments composing the body varies in different species; but such variation would seem, from the interesting researches of Milne-Edwards and Audouin concerning the real organization of articulated tegumentary skeletons, to be rather apparent than real, inasmuch as the discoveries of these distinguished naturalists go far to prove that, whatever the state of consolidation in which the integument is found, the same number of elements or rings may be proved to have originally existed before, by their union, they became no longer distinguishable as separate segments.

(986.) The normal number of these elements Milne-Edwards considers to be twenty-one, seven of which enter into the composition of the head, seven belong to the thorax, and as many appertain to the abdominal region of the body.

(987.) To illustrate this important doctrine let us select a few examples, in order to show the manner in which the progressive coalescence of the segments is effected.

(988.) In *Talitrus* (fig. 196) the cephalic elements are completely united, their existence being only indicated by the several pairs of appendages—one pair, of course, belonging to each ring. The first ring of the cephalic region, in this instance, has no external articulated member; but in higher orders the eyes are supported upon long peduncles connected with this element of the skeleton, that may be regarded as the representatives of those limbs which take different names in different regions of the body. The second and third rings support jointed organs, here called *antennæ*; while the several pairs of jaws appertaining to the mouth indicate the existence of so many elements united together in the composition of the head.

Fig. 196.



Talitrus.

(989.) The seven segments of the thorax are still distinct, and each supports a pair of jointed organs, which, being used in locomotion, are called *legs*; the abdominal elements, likewise, are equally free, and have natatory extremities developed from the five posterior rings.

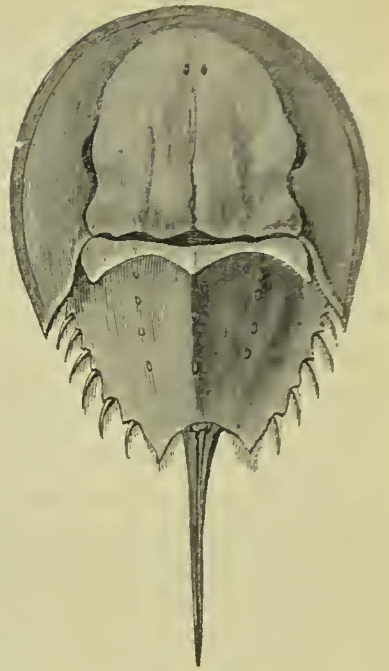
(990.) In the Lobster (*Astacus marinus*) we find not only the cephalic segments anchylosed together, but those of the thorax also; and although the lines of demarcation between them are still recognizable upon the ventral aspect of the body, superiorly the entire thorax and head are consolidated into one great shield (*cephalothorax*), the abdominal segments only remaining distinct and moveable.

(991.) In the Crabs the centralization of the external skeleton is carried to still greater lengths, so as to enable this tribe of Crustaceans to become more or less capable of leaving their native element and walking upon the shores of the sea, or even, in some instances, of leading a terrestrial existence, as in the case of the Land-Crab of the West India Islands. The abdominal segments, however, still remain free, though proportionately of very small dimensions; and, being no longer useful in swimming, the abdomen is folded beneath the enormously-developed thoracic portion of the body.

(992.) In the King-Crab (*Limulus Polyphemus*, fig. 197) even the divisions of the abdomen are obliterated, the whole body being covered by two enormous shields, and the tail prolonged into a formidable serrated spine, of such density and sharpness that in the hands of savages it becomes a dreadful weapon, and is used to point their spears either for the chase or war.

(993.) The reader will at once perceive the strict parallelism that may be traced between the changes which occur during the metamorphoses of Insects, and those observable as we thus advance from the lowest to the most highly organized Crustacean genera; and even the steps whereby we pass from the Annelidan to the Myriapod, and from thence to the Insect, the Scorpion, and the Spider, seem to be repeated, as we thus review the progressive development of the class before us.

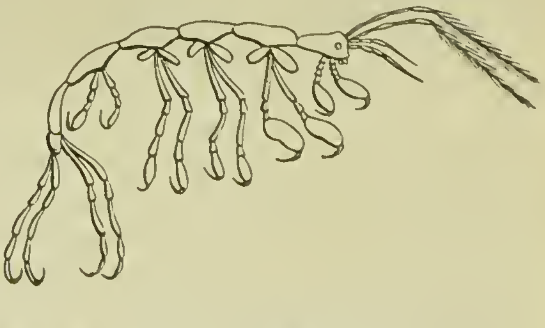
Fig. 197.



Limulus Polyphemus.

(994.) Having thus found that the annuli, or rings, which compose the annulose skeleton may be detected even in the most compactly formed Crustacea, it remains for us to inquire, in the next place, what are the principal modifications observable in the articulated appendages developed from the individual segments. This inquiry is one of considerable interest, inasmuch as it goes to prove that, however dissimilar in outward form, or even in function, the limbs of Crustaceans are mere developments of the same elements, which, as they remain in a rudimentary condition or assume larger dimensions, become converted into instruments of sensation, legs, jaws, or fins, as the circumstances of the case may render needful. In the lower, or more completely annulose forms (figs. 195 and 198), these members are pretty equally developed from all the segments of the body, and are subservient to locomotion, being generally terminated by prehensile hooks, or provided with fin-like expansions; but as we advance to the more perfect genera, the limbs assume such various appearances, and become convertible to so many distinct uses, that they are scarcely to be recognized as consisting of similar elements modified only in their forms and relative proportions.

Fig. 198.



To notice all the varieties which occur in the extensive class before us, would be to weary the reader with tedious and unnecessary details; we shall therefore select the Decapod* division of these animals, as abundantly sufficient for the illustration of this part of our subject. This division, which includes the most highly organized forms, has been divided by writers into three extensive families: the *Macroura*, or Swimming Decapods; the *Anomoura*, which inhabit the empty shells of Mollusca; and the *Brachyura*, or short-tailed species, of which the Crab is a familiar specimen. If we take the common Lobster as an example of the first of these groups, we shall find that there are five pairs of articulated limbs placed upon each side of the mouth, which are evidently adapted to assist in seizing and conveying into the stomach substances used as food. These singular organs, although entitled to be considered as jaws so far as their use would indicate tho name belonging to them, are no less obviously merely modifications of articulated feet; and the term *foot-jaws* has now, by common consent, become the appellation by which they are distinguished.

(995.) The pair of legs which succeeds to the remarkable members last referred to is appropriated to widely different offices. The organs in question are developed to a size far surpassing that attained by any of the other limbs, and are endowed with proportionate strength. Each of these robust extremities is terminated by a pair of strong pincers (*chelæ*); but the two are found to differ in their structure, and are appropriated to distinct uses. That of one side of the body has the opposed edges of its terminal forceps provided with large blunt tubercles, while the opposite claw is armed with small sharp teeth. One, in fact, is used as an anchor, by which the Lobster holds fast by some submarine fixed object, and thus prevents itself from being tossed about in an agitated sea; the other is apparently a cutting instrument for tearing or dividing prey.

(996.) To the *chelæ* succeed four pairs of slender legs, scarcely at all serviceable for tho purposes of locomotion; but the two anterior being terminated by feeble forceps, they become auxiliary instruments of prehension.

(997.) The articulated appendages belonging to all the abdominal segments are so rudimentary that they aro no longer recognizable as assistants in progression; and it is at once evident, when we examine the manner in which the *Macroura* use their tails in swimming, that the development of large organs in this position would materially impede the progress of animals presenting such a construction: the *false feet*, as these organs are called, are therefore merely available as a means of fixing the ova which the female Lobster carries about with her attached beneath her abdomen.

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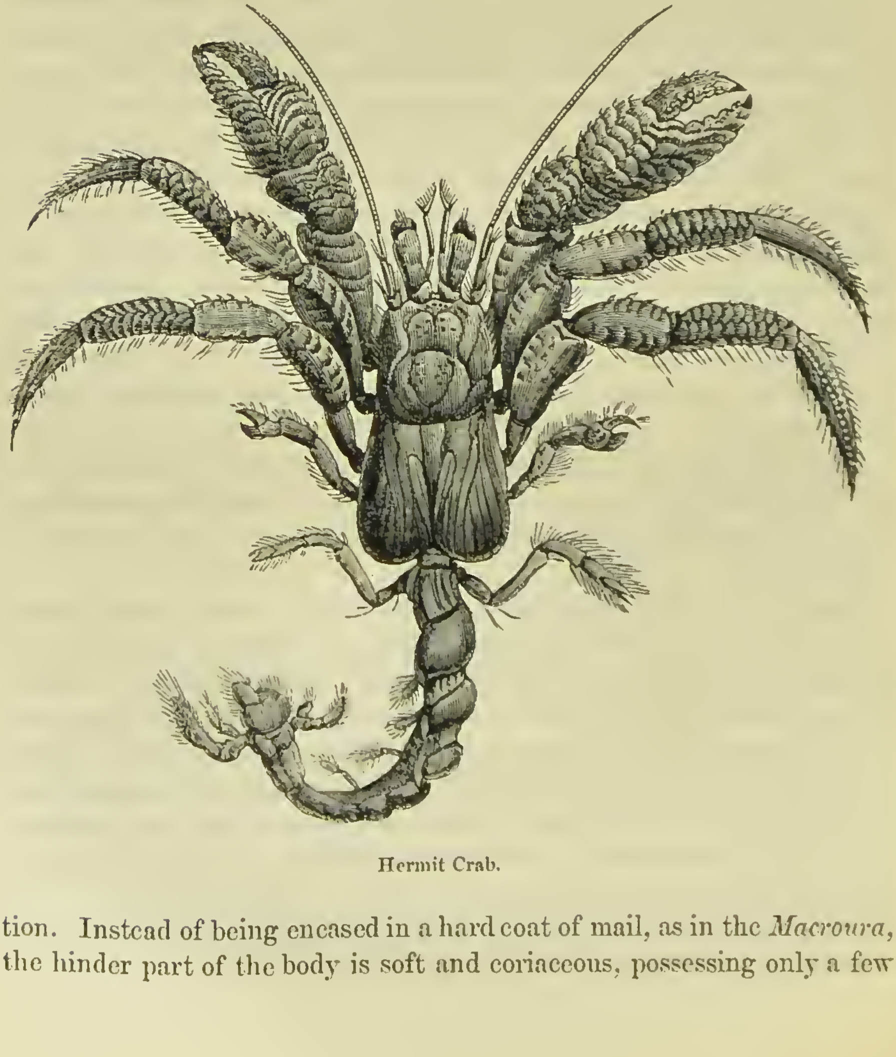
* So called from the circumstance of their having five pairs of limbs so largely developed as to become ambulatory or prehensile organs.

(998.) The tail is the great agent of locomotion in all the *Macroura* or large-tailed Decapods; and for this purpose it is terminated by a fin, formed of broad calcareous lamellæ, so arranged that, while they will close together during the extension of the tail, and thus present the least possible surface to the water, they are brought out to their full expansion by the down-stroke of the abdomen; and such is the impulse thus given, that, as we are credibly informed, a Lobster will dart itself backwards to a distance of eighteen or twenty feet by one sweep of this remarkable locomotive instrument.

(999.) If we now pass on to the consideration of the *Anomourous Decapods,* we find that the external organs above enumerated, although existing in precisely similar situations, are so far modified in their construction and relative proportions as to become suited to a mode of life widely different from that led by the members of the last division. The *Anomoura,* as their name imports, have tails of very unusual conformation. Instead of being encased in a hard coat of mail, as in the *Macroura,* the hinder part of the body is soft and coriaceous, possessing only a few

Fig. 199.

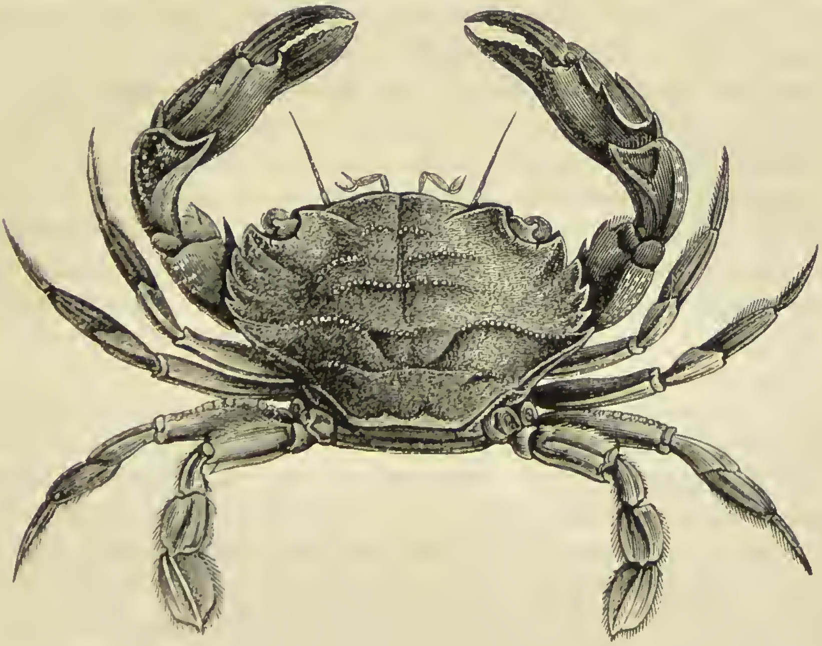


Hermit Crab.

detached calcareous pieces—analogous, it is true, to those found in the Lobster, but strangely altered in structure.

(1000.) These animals (fig. 199), usually known by the name of Soldier Crabs, or Hermit Crabs, frequent level and sandy shores, and, from their defenceless condition, are obliged to resort to artificial protection. This they do by selecting an empty turbinated shell of proportionate size, deserted by some gasteropod mollusk, into which they insinuate their tail, and, retreating within the recesses of their selected abode, obtain a secure retreat, which they drag after them wherever they go, until, by growing larger, they are compelled to leave it in search of a more capacious lodging. The wonderful adaptation of all the limbs to a residence in such a dwelling cannot fail to strike the most incurious observer. The *chelæ*, or large claws, differ remarkably in size; so that, when the animal retires into its concealment, the smaller one may be entirely withdrawn, while the larger closes and guards the orifice. The two succeeding pairs of legs, unlike those of the Lobster, are of great size and strength, and, instead of being terminated by pincers, end in strong pointed levers, whereby the animal can not only crawl, but drag after it its heavy habitation. Behind these locomotive legs are two feeble pairs, barely strong enough to enable the Soldier-Crab to shift its position in the shell it has chosen; and the false feet attached to the abdomen are even still more rudimentary in

Fig. 200.



Swimming Crab.

their development. But the most singularly altered portion of the skeleton is the fin of the tail, which here becomes transformed into a kind of holding apparatus, by which the creature retains a firm grasp upon the bottom of its residence.

(1001.) In the *Brachyura*, or Crabs, we have at once, in the concentration observable in all parts of the skeleton, an indication of its being formed for progression on land, or at least for creeping at the bottom of the sea. The tail, the great instrument of locomotion in the Lobster, is here reduced to a rudiment, and the fin at its extremity entirely obliterated; the *chelæ* still continue to be the most powerfully developed of the extremities; while the legs, the principal locomotive agents, are either terminated by simple points, as in those species which are most decidedly terrestrial in their habits, or else, in the Swimming Crabs, the posterior pair become expanded into flattened oars useful in natation (fig. 200).

(1002.) From the extreme hardness and unyielding character of the tegumentary skeleton in Crustaceans, a person unacquainted with the history of these animals would be at a loss to conceive the manner in which their growth could be effected. In insects we have seen that all increase of size occurs prior to the attainment of the perfect condition, and expansion is provided for by the moults or changes of skin which take place during the development of the larva; but the Crustacean, having acquired its mature form, still continues to grow, and that until it acquires in many instances a size far larger than that which any insect is permitted to arrive at.

(1003.) The plan adopted in the case before us, whereby growth is permitted, is attended with many extraordinary phenomena. At certain intervals the entire shell is cast off, leaving the body for the time unfettered indeed as regards the capability of expansion, but comparatively helpless and impotent until such time as a new shell becomes secreted by the dermis, and by hardening assumes the form and efficiency of its predecessor.

(1004.) We are indebted to Reaumur*, who watched the process in the Cray-fish (*Astacus fluviatilis*), for the first account of the mode in which this change of shell is effected. In the animal above mentioned, towards the commencement of autumn, the approaching moult is indicated by the retirement of the Cray-fish into some secluded position, where it remains for some time without eating. While in this condition, the old shell becomes gradually detached from the surface of the body, and a new and soft cuticle is formed underneath it, accurately representing, of course, all the parts of the old covering which is to be removed; but as yet little calcareous matter is deposited in the newly-formed integument. The creature now becomes violently agitated, and, by various contortions of its body, seems to be employed in loosening

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* Mém. de l'Acad. des Sciences, 1718.

thoroughly every part of its worn-out covering from all connexion with the recently-secreted investment. This being accomplished, it remains to extricate itself from its imprisonment—an operation of some difficulty; and when the nature of the armour to be removed is considered, we may well conceive that not a little exertion will be required before its completion. As soon as the old case of the cephalothorax has become quite detached from the cutis by the interposition of the newly-formed epidermic layer, it is thrown off in one piece, after great and violent exertion; the legs are then withdrawn from their cases, also after much struggling; and, to complete the process, the tail is ultimately, by long-continued efforts, extricated from its calcareous covering, and the entire coat of mail which previously defended the body is discarded and left upon the sand. The phenomena which attend this renovation of the external skeleton are so unimaginable, that it is really extraordinary how little has been done towards elucidating the nature of the operation. The first question which presents itself is, how are the limbs liberated from their confinement? for, wonderful as it may appear, the joints even of the massive *chelæ* of the Lobster do not separate from each other, but, notwithstanding the great size of some of the segments of the claw, and the slender dimensions of the joints that connect the different pieces, the cast-off skeleton of the limb presents exactly the same appearance as if it still encased the living member. The only way of explaining the circumstance is to suppose that the individual pieces of the skeleton, as well as the soft articulations connecting them, split in a longitudinal direction, and that, after the abstraction of the limb, the fissured parts close again with so much accuracy that even the traces of the division are imperceptible. But this is not the only part of the process which is calculated to excite our astonishment: the internal calcareous septa from which the muscles derive their origins, and the tendons whereby they are inserted into the moveable portions of the outer shell, are likewise stated to be found attached to the exuviæ; even the singular dental apparatus situated in the stomach, of which we shall speak hereafter, is cast off and re-formed! And yet, how is all this accomplished? how do such parts become detached? how are they renewed? We apprehend that more puzzling questions than these can scarcely be propounded to the physiologist; nor could more interesting subjects of inquiry be pointed out to those whose opportunities enable them to prosecute researches connected with their elucidation*.

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* Since writing the above, I have been fortunate in procuring a very good specimen of *Astacus fluviatilis*, obtained soon after casting its shell, and also its newly cast-off covering, both of which are in excellent preservation. The following is a description of the appearances observed in each:—All the pieces of the exuviæ were connected together by the old articulations, and accurately represented the external form of the complete animal,—the *carapace*, or dorsal shield of the cephalothorax, alone being detached, having been thrown off in one piece. The pedicles of the eyes and external corneæ, as well as the antennæ, remaind *in situ*, the corresponding parts

(1005.) The structure of the articulations which unite the different segments of the skeletons of the Articulata, and the general arrangement of their muscular system, have already been described; and in the class before us, these parts of their economy offer no peculiarities worthy of special notice.

(1006.) Throughout all the Crustacean families the alimentary canal exhibits great simplicity of arrangement, and consists of a short but capacious œsophagus, a stomachal dilatation or cavity in which is contained a singular masticatory apparatus, and a straight and simple intestinal tube, which passes in a direct line from the stomach to the last segment of the abdomen, where it terminates.

(1007.) The description of these parts as they exist in the Lobster, will give the reader a sufficiently correct idea of their general disposition and structure; nor are we acquainted with any class of animals in which so little variety in the conformation of this portion of the system is to be met with.

(1008.) The œsophagus is covered at its origin by the several pairs of foot-jaws already alluded to, the most internal of which forms a decided cutting apparatus, resembling a pair of strong shears, while the rest are only instruments of prehension, or, perhaps, of sensation also.

having been drawn out from them as the finger from a glove; and no fissure of the shell or rupture of the ligaments connecting the joints was anywhere visible in these portions of the skeleton. The auditory tubercles, and the membrane stretched over the orifice of the ear, occupied the same position as in the living Cray-fish. The jaws, foot-jaws, and ambulatory feet retained their original connexions, with the exception of the right *chela*, which had been thrown off before the moult began; and the segments of the abdomen, false feet, and tail-fin exactly resembled those of the perfect creature. Even the internal processes derived from the thoracic segments (*apodemata*) rather seemed to have had the flesh most carefully picked out from among them, than to have been cast away from a living animal. But perhaps the most curious circumstance observable was, that attached to the base of each leg was the skin which had formerly covered the branchial tufts, and which, when floated in water, spread out into accurate representations of those exquisitely delicate organs. No fissure was perceptible in any of the articulations of the small claws; but in the chela each segment was split in the neighbourhood of the joints, and the articulating ligaments ruptured. The lining membrane of the stomach was found in the thorax, having the stomachal teeth connected with it: from its position, it would seem that the animal had dropped it into the place where it lay, before the extrication of its limbs was quite accomplished. The internal tendons were all attached to the moveable joint of each pair of forceps, both in the chela and in the two anterior pairs of smaller ambulatory legs.

On examining the animal which had extricated itself from the exuviæ described above, the shell was found to be soft and flexible, but contained a sufficiency of calcareous matter to give it some firmness, especially in the claws. The tendons of the forceps were still perfectly membranous, presenting a very decided contrast when compared with the old ones affixed to the discarded shell. The stump of the lost chela had not as yet begun to sprout, and the extremity was covered by a soft black membrane. The jaws were quite hard and calcified, as likewise were the teeth contained in the stomach.

From the mouth, the œsophagus runs directly upwards to the stomach, which is a considerable viscus (fig. 201, *a*), a large portion of it being situated in that region of the cephalothorax which we should be tempted to consider as the head of the animal. The pyloric extremity of the stomach is strengthened with a curious framework of calcareous pieces imbedded in its walls, and so disposed as to support three large teeth placed near the orifice of the pylorus; and being moved by strong muscles, teeth so disposed no doubt form an efficient apparatus for bruising the food before it is admitted into the intestine.

(1009.) The intestine itself (*b b b*) runs in a direct course to the tail, imbedded between the two great lateral muscular masses that move the abdominal segments, and terminates upon the ventral surface of the central lamella of the terminal fin, in a rounded orifice closed by a sphincter muscle.

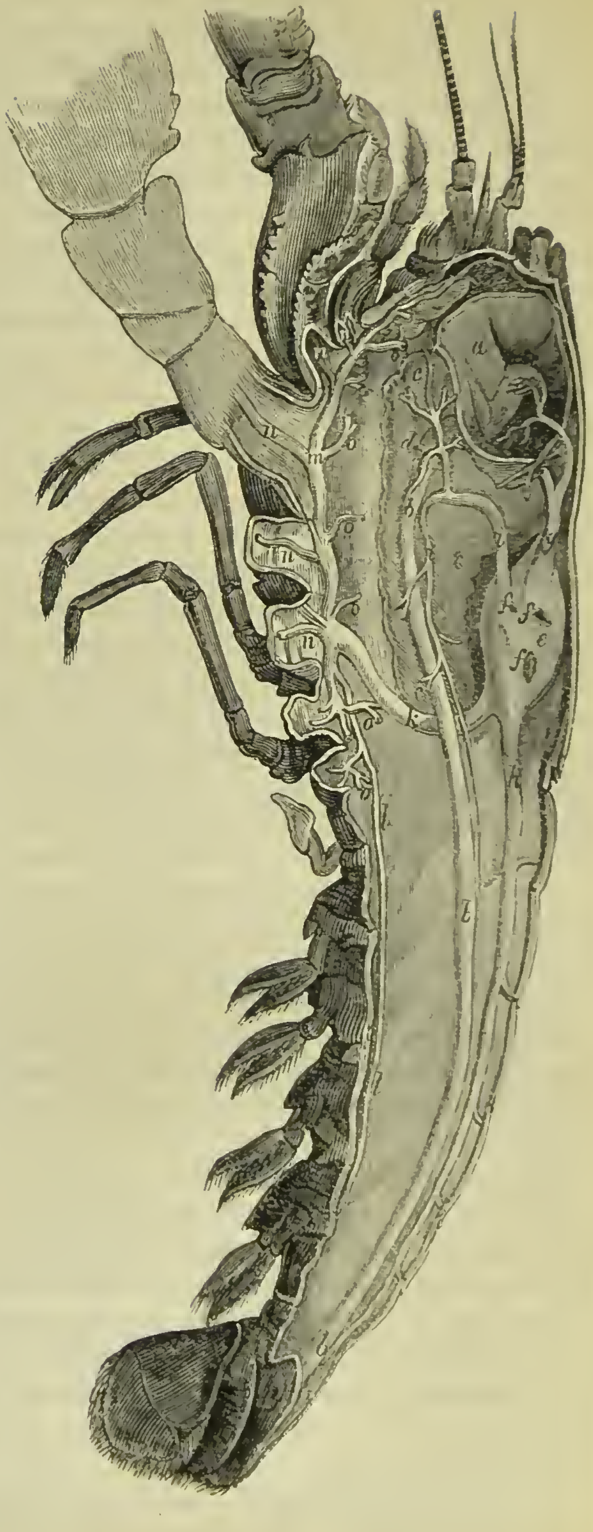
(1010.) The liver (*c c c*), one half of which has been removed in the engraving, consists of two large symmetrical masses, enclosing between them the pyloric portion of the stomach and a third part of the length of the intestine. When unravelled, the minute structure of the liver exhibits an immense assemblage of secerning cæca agglomerated into clusters, from each of which a duct emanates; and the continued union of the ducts so formed ultimately gives origin to the common hepatic canal (*d*), which pours the bile derived from that division of the liver to which it belongs into the intestine, at a very short distance from its commencement at the pylorus. A little below the insertion of the two bile-ducts, a solitary long and slender cæcum enters the intestine; but the nature of the secretion furnished by this organ is unknown.

(1011.) In the highest Crustacea, as the *Decapoda*, in which legs of an ambulatory character become such important locomotive agents, it is principally to the origins of these legs that we find the breathing apparatus appended; and their active motion will consequently powerfully contribute to the complete aëration of the blood. But let us first examine the structure of the branchiæ themselves in this highly-organized division, and subsequently we will speak of their arrangement and connexions.

(1012.) In the Lobster, and many other *Macroura*, the branchiæ (fig. 204, *m m*), are pyramidal tufts, consisting of a central stem covered over with vascular filaments disposed perpendicularly to its axis, in such a manner that each of these organs, when detached, resembles in some degree a small brush: on cutting the stem across, it is found to enclose an artery and a vein, from which innumerable branches are given off to the horizontal filaments; so that the latter constitute a respiratory surface of great extent, which is most freely exposed to the surrounding medium.

(1013.) In the Crabs and Anomoura the structure of the branchiæ is somewhat different; for in these divisions the cylindrical filaments are

Fig. 201.



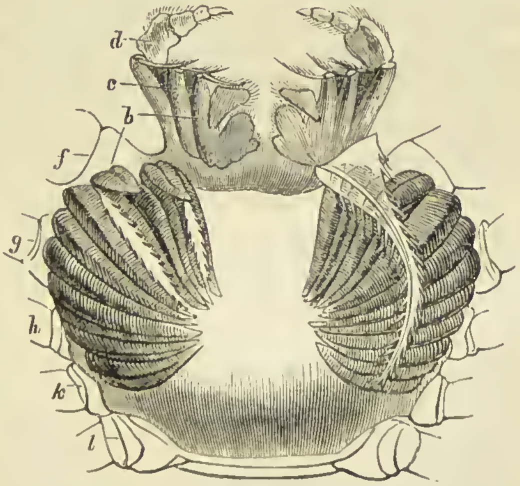
A side view of the arterial system in the Lobster. Nearly one half of the body is removed to show the deeper-seated vessels: *a*, the stomach, which has one half removed, so as to show the cavity of that viscus; *b b b*, the intestine, which is one straight tube; *c c c*, the lobes of the liver of the left side, the right being removed; *d*, hepatic duct, entering the intestine; *e*, the heart; *f f f*, three orifices, guarded by valves, whereby the venous system communicates with the heart; *g*, the anterior or antennal arteries; *h*, the posterior or superior caudal artery; *i*, the hepatic artery; *k*, a large artery going down from the posterior end of the heart, principally supplying the feet and gills (sternal artery); *l* is a small artery passing back along the under surface of the tail, and lost in the muscles of that part (inferior caudal artery); *m*, the trunk of the artery *k* bent forwards along the fore part of the thorax, giving off branches on each side to the feet and gills; *n n n*, the branches going to the feet; *o o o*, the branchial arteries.

replaced by broad lamellæ laid one above the other; but in every other respect the arrangement is the same.

(1014.) The respiratory organs above mentioned are lodged in two extensive cavities, or branchial chambers, placed upon the sides of the body, covered by the broad shield of the cephalothorax (fig. 203), and lined by a membrane which is reflected upon the root of each branchia, so as to become continuous with the delicate layer that invests every filament or vascular lamella that enters into its composition.

(1015.) The branchial chambers are in free communication with the external medium by means of two large apertures, through one of which the water enters, while it as constantly flows out through the other. The afferent canal is generally a wide slit that allows the water freely to penetrate to the interior of the branchial cavity; but the passage whereby the respired fluid escapes after passing over the branchiæ is provided with a valvular apparatus so disposed as to produce a continual current in the water contained in the chamber, and thus, by ensuring its perpetual agitation, effectually to provide for its constant renewal. The mechanism is as follows:—The aperture by which the water issues is in the neighbourhood of the mouth, and is closed by a broad semi-membranous plate (*flabellum*) derived from the root of the second pair of foot-jaws; so that every motion of these foot-jaws impresses a corresponding movement upon the valve-like *flabellum*, and in this manner urges on the passage of the water out of the cavity in which the branchiæ are lodged.

Fig. 202.



Respiratory organs of the Crab: *b*, *c*, *d*, foot-jaws, from the bases of which the *flabella* are derived; *f*, *g*, *h*, *k*, *l*, ambulatory legs.

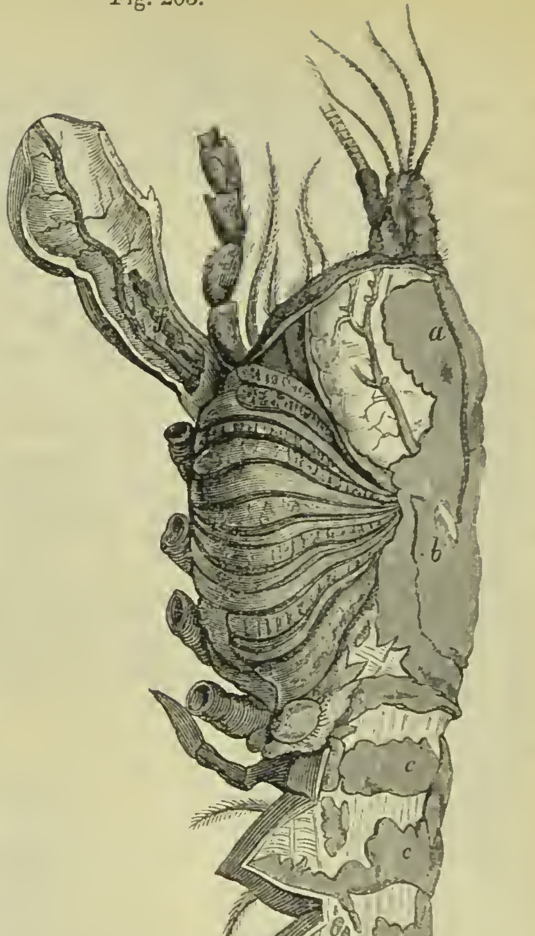
(1016.) But there are other means whereby the action of the limbs is made to assist in the perfection of the respiratory process. Thus, in the Lobster, the third pair of foot-jaws, and each pair of ambulatory legs, except the last, supports a flabelliform plate (fig. 204, *n*), the movements of which must likewise keep the fluid respired in a state of agitation, and moreover, by gently squeezing and compressing the respiratory tufts, powerfully contribute to the perfect renovation of the water in contact with the surfaces of the branchiæ.

(1017.) In the Crab genera the arrangement is slightly modified; for here there are three *flabella*, derived exclusively from the roots of the foot-jaws (fig. 202, *b*, *c*, *d*): of these, two are imbedded among the branchiæ; while the third, as represented in the figure, extends in a crescentic form over the external surface of the whole series of those organs. The end answered in this case is obviously the same as that accomplished in the Lobster, in a different and perhaps more efficient manner.

(1018.) In the lowest Crustacea the heart is a long dorsal vessel, not very dissimilar in form and disposition from that of insects, but, of course, giving off arteries for the distribution of the blood, and receiving veins through which the blood, having accomplished its circuit, is returned.

(1019.) In the *Decapoda* the organ becomes more centralized; and in the Lobster (fig. 201, *e*) the heart is found to be an oval viscus, situated in the mesial line of the body, beneath the posterior part of the cephalo-thorax; it is composed of strong muscular bands, and contains a single cavity of considerable size. The contractions of this heart may readily be witnessed by raising the superjacent shell in the living animal.

Fig. 203.



Venous system of the Lobster: *a*, side view of the venous sinus covering the stomach; *b*, side view of the sinus surrounding the heart (the letter is placed near one of the valvular orifices by which the venous blood is admitted into the ventricle); *c c c c*, superficial dorsal sinuses.

(1020.) Several large arteries are derived from the above-mentioned simple heart. A considerable trunk (fig. 201, *g*) goes from its anterior extremity to supply the eyes, antennæ, stomach, and neighbouring organs; another, tho *hepatic* (*i*), which is sometimes double, supplies the two lobes of the liver; a third large vessel (*h*) supplies the abdominal or caudal region; and a fourth, the *sternal*, derived from the posterior apex of the heart, bends down to the ventral aspect of the body, where it divides—the posterior division (*l l*) supplying the lower parts of the abdomen, while the anterior and larger division (*m*) gives off branches to the legs and foot-jaws (*n n n n*); it likewise furnishes other vessels (*o o o o*), which are distributed through the branchiæ.

(1021.) The venous system is made up of large and delicate sinuses that communicate freely with each other, and receive the blood from all parts of the body. Those of the dorsal region are represented in the opposite page (fig. 203): a large venous sinus (*a*) occupies the cephalic region and covers the stomach; another cavity (*b*) lies immediately above the heart; and a series of smaller chambers (*c c c c*) are situated above the muscles of the caudal region. These cavities, notwithstanding their apparent extent, are very shallow, so that, upon a transverse section, their dimensions are by no means so great as a superficial view would indicate. The sinus (*b*), or that placed immediately over the heart, communicates with that viscus by short trunks, the terminations of which in the heart are guarded by valves (fig. 201, *f f f*), so disposed as to allow the blood to pass from the sinus into the heart, but prevent its return in an opposite direction.

Such is the apparatus provided in the Lobster for the circulation of the blood. Our next inquiry must be concerning the course that it pursues during its circuit through the body.

(1022.) MM. Audouin and Milne-Edwards*, after very minutely examining this subject, came to the conclusion that the heart is purely of a systemic character, being only instrumental in propelling the blood through the body, but having nothing to do with the branchial circulation; they conceived that the circulating fluid, having been collected in the venous sinuses, was brought to the roots of the branchiæ, over which it was distributed by venous tubes, and then returned to the heart by vessels, which they call *branchio-cardiac*, to recommence the same course. The appended figures, however, which are accurately copied from engravings of the Hunterian drawings in the collection of the Royal College of Surgeons of England†, would seem to give great reason to doubt the accuracy of the conclusions arrived at by the eminent naturalists referred to, and to show that the heart, instead of being purely systemic, is partly branchial, and impels the blood, not through the body only, but also to the respiratory organs. This view of the subject, which we are disposed to consider as the most correct, is exhibited in the diagram annexed. Setting out from the heart, we find that the blood goes to all parts of the body through the different arterial trunks, and by the great sternal artery (fig. 201, *k*) is conveyed to the legs, foot-jaws, and false feet. But from this same artery (*m*), vessels (*o o o o*) are furnished to the branchiæ. The branchial arteries so derived (fig. 204, *g*) subdivide into secondary trunks (*h h h*), which ramify through the individual branchiæ and supply all their appended filaments. Having undergone exposure to the respired medium, the blood is again collected from the branchiæ by branchial veins (*k k k*), represented on the opposite side of the body, and conveyed by the large vessel (*l*) to the dorsal sinus (fig. 203, *b*), where, being mixed up with the general mass of blood contained in the sinus, the circulating fluid is admitted into the heart through the valvular orifices (fig. 204, *d d*), to recommence the same track.

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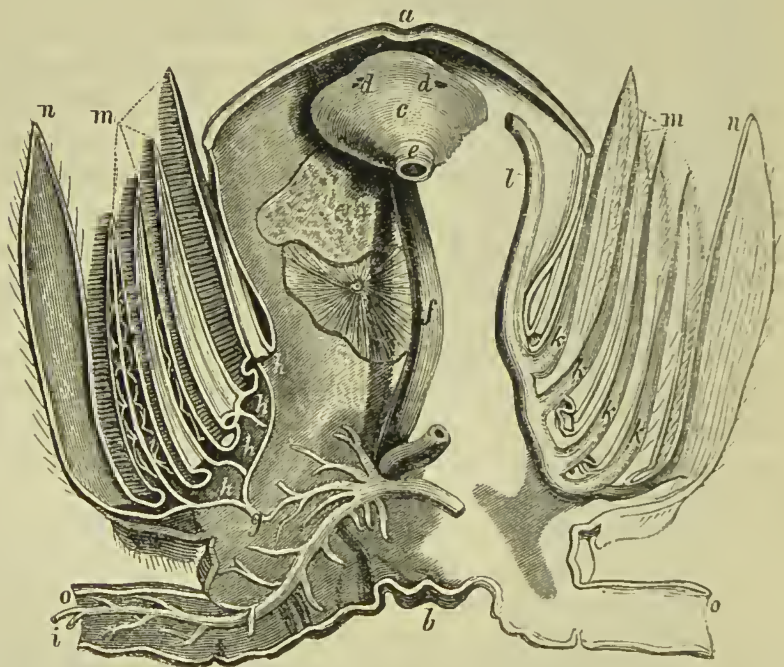
* "Recherches Anatomiques et Physiologiques sur la Circulation dans les Crustacés," Ann. des Sci. Nat. tom. ii.

† Catalogue of the Physiological Series of Comparative Anatomy contained in the Museum of the Royal College of Surgeons of England, vol. ii.

Fig. 204.



Transverse section of the body of a Lobster, just behind the heart: *a*, cut edge of the shell of the back; *b*, the under surface or sternal aspect; *c*, the posterior end of the heart; *d d*, two orifices of veins entering the heart; *e*, cut end of the superior caudal artery; *f*, the trunk of the large artery (sternal) going to the legs and gills (*k* in fig. 201); *g*, trunk of an artery going to supply one tier of gills; *h h h*, the branches going to each gill; *i*, artery of the leg; *k k k k*, the internal vessels or veins from each gill; *l*, the common trunk or branchial vein; *m m*, the gills; *n n*, the *flabella*, or laminæ subservient to the movement and renewal of the respired medium; *o o*, basal joints of the legs.

(1023.) In the Crustacea, as in the class of Insects, the blood* occupies all the interspaces left between the various viscera, as well as the still smaller lacunæ situated among the muscular fibres or underneath the skin: but the heart, instead of opening immediately into this system of intercommunicating cavities, as among the true insects, is continuous with a special system of tubes, the walls whereof are well defined, and of which the peripheral branches ramify in the substance of all the organs of the body, thus constituting a very complete arterial system, although, by their ultimate ramifications, the centrifugal vessels thus formed become continuous with and lost amongst the interstitial lacunæ of the body, which in their turn communicate with more considerable cavities situated between the viscera; so that the blood ejected by the heart and arteries, arriving in the last ramifications of those tubes, escapes into the general interstitial lacunary system, by the intermedium of which it returns towards the heart. Thus the circulating fluid is brought into direct contact with all the viscera, and fills up the abdominal cavity, so that not until after it has passed through the respiratory apparatus does it again find itself enclosed in vessels properly so called.

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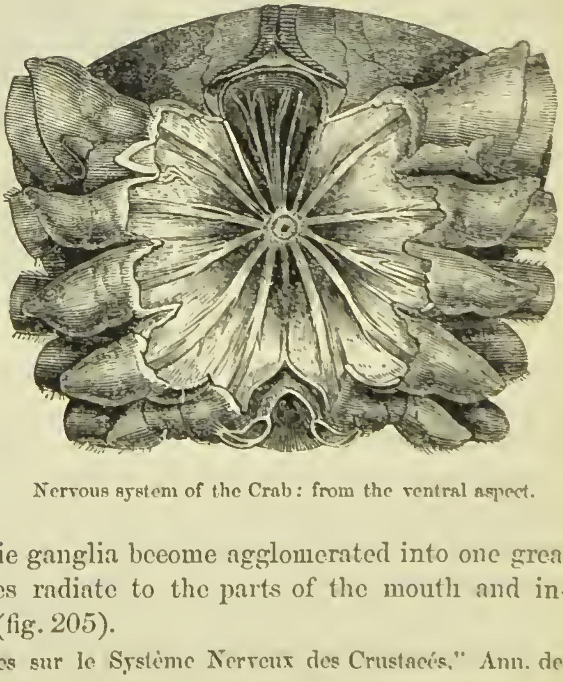
* Milne-Edwards, *loc. cit.*

(1024.) As might be anticipated from an examination of the external configuration of the different families comprised in the extensive class we are now considering, the nervous system is found to pass through all those gradations of development which we have found gradually to present themselves as we have traced the Homogangliata from the lowest to the most highly organized types of structure. In the most imperfect Crustacea, indeed, we find a simplicity of arrangement greater than any hitherto pointed out even in the humblest Annelida—a disposition of parts which, theoretically, might have been expected to exist, but has only been distinctly recognized in the class before us.

(1025.) We have all along spoken of the nervous centres of the Articulata as arranged in symmetrical pairs, although in no example which has yet occurred to our notice have we been able strictly to point out the accuracy of such a view of the subject. The two lateral masses of the supra-œsophageal ganglion are found united into one brain in the humblest forms of annulose animals; and even in the ganglia forming the ventral series, although we might presume each to be composed of two symmetrical halves, the divisions are most frequently so intimately blended, that their distinctness is not susceptible of anatomical demonstration. In some of the Crustacea, however, among those species which have the segments of their external skeleton most perfectly separate and distinct, the nervous system is found to present itself in such a condition that the division into lateral halves is perfectly evident; and from this condition their progressive coalescence may be traced, step by step, until we arrive at a state of concentration as remarkable as that already noticed in the most elevated of the Arachnidans. It is to Milne-Edwards and Audouin that we are indebted for the interesting particulars connected with this part of our subject; and the results of their investigations are of such great physiological importance*, that the following condensed account of their labours cannot be omitted in this place. In *Talitrus*, every pair of ganglia consists of two separate nuclei of nervous substance, united by a transverse band so disposed as to bring them into communication with each other, while an anterior and posterior nervous filament derived from each unites it with the preceding and following ganglia of the same side of the body: even the encephalic mass is composed of two lateral portions united by a cord passing between them. All these pairs of ganglia (thirteen in number, corresponding with the number of the segments of the body) are exact counterparts of each other both in size and figure, so that none seems to preponderate in energy over the rest; but the anterior or encephalic pair alone communicates with the eyes and antennæ, the only organs of the senses as yet discernible.

(1026.) In *Oniscus Asellus*, a concentration of the elements composing the nervous system above described is discernible; and this is found to be indicated by incipient approximation, which takes place in *two directions*, one longitudinal, the other transverse. In the first place, the entire number of pairs of ganglia is reduced to ten, three pairs having become obliterated by coalescence; and moreover, while the central portions still consist of two lateral masses each, the first and last pairs are united into single ganglia. As we rise to higher forms the coalescence still proceeds; all the pairs of ganglia soon become united in a transverse direction, and gradually the whole chain becomes shorter by the fusion of several pairs into larger and more powerful masses.

Fig. 205.



Nervous system of the Crab: from the ventral aspect.

(1027.) In the *Crab* (which, from its terrestrial habits, holds a position among the Crustacea equivalent to that which the Spiders occupy among other Articulata), this centralization is carried to the utmost extent, and all the abdominal and thoracic ganglia become agglomerated into one great centre, from which nerves radiate to the parts of the mouth and instruments of locomotion (fig. 205).

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* "Recherches Anatomiques sur le Système Nerveux des Crustacés," Ann. des Sci. Nat. t. xiv.

(1028.) But this change in the condition of the nervous system is not only observable as we proceed from species to species, as they rise higher in the scale of development; similar phenomena are met with in watching the progress of any individual belonging to the more perfect families, as it advances from the embryo to its mature condition. Thus, in the Cray-fish (*Astacus fluviatilis*), Rathke* observed that, when first perceptible, the nervous system consisted of eleven pairs of ganglia, perfectly distinct from each other, and situated on each side of the mesial line of the body. The first six pairs then unite transversely, so as to form as many single masses, from which the nerves of the mandibles and foot-jaws emanate; while the five posterior, from which the nerves of the ambulatory extremities are given off, remain separate. Such is the state at birth, or on leaving the egg; but further changes occur before the Cray-fish arrives at maturity. The four anterior ganglia, which supply nerves to the mandibles and foot-jaws, are, by degrees, all consolidated into one mass, and the fifth and sixth likewise coalesce, while the other pairs continue permanently distinct. The reader will at once recognize the resemblance between these changes and those already described as taking place during the progress of evolution in the Caterpillar: the same great law is, in fact, in operation in both cases, and the same results are obtained from the completion of the process†.

(1029.) From a review of the above facts, Milne-Edwards and Audouin arrived at the following conclusions:—1st. That the nervous system of Crustacea consists uniformly of medullary nuclei (ganglions), the normal number of which is the same as that of the segments or rings of the body. 2nd. That all the modifications encountered, whether at different periods of the development or in different species of the series, depend especially on the more or less complete approximation of these nuclei, and on an arrest of development in some of their number. 3rd. That approximation takes place from the sides towards the mesian line, as well as in a longitudinal direction.

(1030.) In the Crab, the distribution of the nerves is briefly as follows:—The encephalic mass, or brain, which still occupies its position above the œsophagus, and joins the abdominal centre by two long cords of connexion (fig. 206), gives off nerves to the eyes, and muscles connected with them, as well as to the antennæ and neighbouring parts.

(1031.) Near the centre of each division of the nervous collar that surrounds the œsophagus is a ganglionic enlargement, from which arises a nerve that runs to the mandibles, and also a very important branch, apparently the representative of the *nervus vagus* of insects. This, after ramifying largely upon the coats of the stomach, joins that of the opposite side, and, assuming a ganglionic structure, is ultimately lost upon the intestine.

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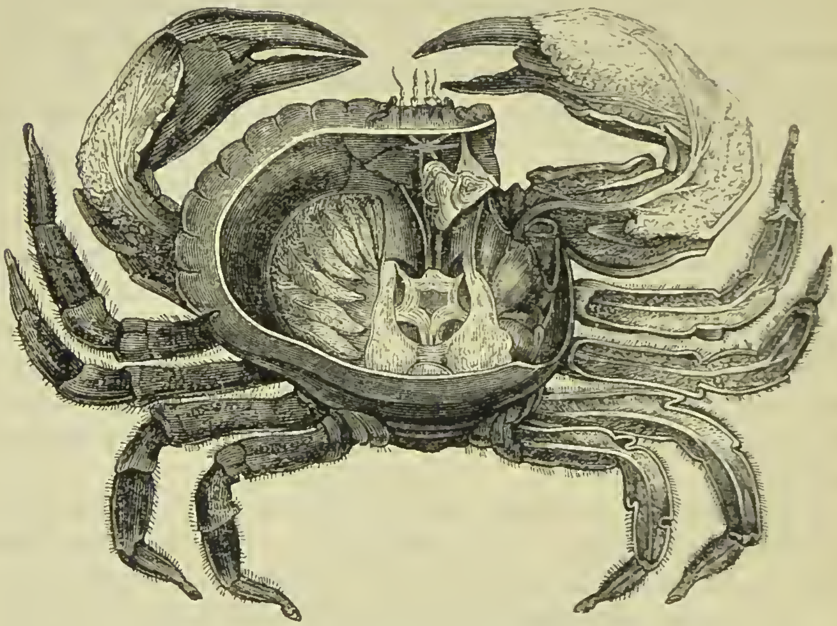
* "Untersuchungen über die Bildung des Flusskrebses," Ann. des Sci. Nat. t. xx.

† For a minute account of the arrangement of the nervous system in these animals, the reader is referred to the Cyclopædia of Anatomy and Physiology, art. "Crustacea," by Dr. Milne-Edwards.

(1032.) The nerves of the extremities, derived from the central abdominal ganglion, are represented in the annexed figure (fig. 206), which requires no explanation*.

Fig. 206.



Nervous system of the Crab : from the dorsal aspect.

(1033.) We have already (§ 858), when describing the nervous system of insects, hinted at the probable existence in the HOMOGANGLIATA of distinct tracts of nervous matter in the composition of the central chain of ganglia, and in the filaments whereby they are connected with each other: reasoning therefore from analogy, it seems fair to presume that, if this be the case, such tracts correspond with the sensitive and motor columns which have been distinctly proved to exist in the spinal axis of vertebrate animals. It is to Mr. Newport that we are indebted for the first indication of this interesting fact†; and the accuracy of his observations is readily demonstrable by a careful examination of the ganglionic chain of the Lobster and other large Crustacean species. Each ganglionic enlargement is, upon close inspection, clearly seen to consist of two portions: first, of a mass of cineritious nervous substance forming the inferior aspect of the ganglion, and of a cord of medullary or fibrous matter which passes over the dorsal or superior aspect, and appears to be distinct from the grey substance over which it passes: supposing therefore the longitudinal chain to consist of anterior and posterior fasciculi, as in the *medulla spinalis*, we have the anterior columns communicating with grey substance, while the posterior are unconnected therewith, but are continued over the ganglion instead of becoming amalgamated with its substance. Another fact which favours Mr. Newport's view of the subject is derived from an examination of the manner in which the nerves given off from the central axis take their origin; for some of them undoubtedly proceed from the cineritious portion of the ganglionic swelling, while others, derived from the upper column, not only have no connexion with the grey matter, but arise at some distance from the ganglionic mass: judging therefore by the laws at present established in physiology, there seems reason to suppose that the anterior, or, rather, inferior fasciculi are connected with sensation, while the superior constitute the motor tract.

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* *Vide* Swan, Illustrations of the Comparative Anatomy of the Nervous System. London, 4to.

† Phil. Trans. 1834.

(1034.) The reader who is conversant with human physiology will at once perceive that this arrangement is precisely the reverse of that met with in Man and other Vertebrata; and this consideration, apparently of little importance, has given rise to a variety of curious speculations—some anatomists having even gone so far as to assert that all the organs of articulated animals are in reality placed in a similar inverted position.

(1035.) A more interesting inquiry connected with this part of our subject is, concerning the extent to which the ARTICULATA are susceptible of pain. Is it really true in philosophy, as it has become a standing axiom in poetry, that

> "The poor beetle, that we tread upon,
> In corporal sufferance feels a pang as great
> As when a giant dies"?

(1036.) This is a question upon which modern discoveries in science entitle us to offer an opinion; and the result of the investigation would seem to afford more enlarged views relative to the beneficence displayed in the construction of animals than the assertion of the poet would lead us to anticipate. Pain, "Nature's kind harbinger of mischief," is only inflicted for wise and important purposes—either to give warning of the existence of disease, or as a powerful stimulus prompting to escape from danger. Acute perceptions of pain could scarcely, therefore, be supposed to exist in animals deprived of all power of remedying the one or of avoiding the other. In Man, the power of feeling pain indubitably is placed exclusively in the brain; and if communication be cut off between this organ and any part of the body, pain is no longer felt, whatever mutilations may be inflicted.

(1037.) The *medulla spinalis*, which, as we shall see hereafter, corresponds to the ventral chain of ganglia in articulated animals, can perceive external impressions and originate motions, *but not feel pain*; hence we may justly conclude that, in the Homogangliata likewise, the supra-œsophageal ganglia (the representatives of the brain, and the sole correspondents with the instruments of the higher senses) are alone capable of appreciating sensations of a painful character. Thus, then, we arrive at a very important conclusion, namely, that the perception of pain depends upon the development of the encephalic masses, and consequently that as this part of the nervous system becomes more perfect, the power of feeling painful impressions increases in the same ratio—or, in other words, that inasmuch as the strength, activity, and intelligence of an animal, by which it can escape from pain, depend upon the perfection of the brain, so does the perception of torture depend upon the condition of the same organ. How far the feeling of pain is acutely developed in the animals we are now considering is deducible from every-day observation. The Fly seized by the leg will leave its limb behind, and alight with apparent unconcern to regale upon the nearest sweets within its reach; the Caterpillar enjoys, to all appearance, a tranquil existence while the larvæ of the Ichneumon, hatched in its body, devour its very viscera; and in the Crustacea before us, of so little importance is the loss of a leg, that the Lobster will throw off its claws if alarmed by the report of a cannon.

(1038.) We learn from Dr. Williamson* that the shell of the Decapods, in its most complete form, consists of three strata: namely, 1. a horny structureless layer, covering the exterior; 2. a cellular stratum; and 3. a laminated tubular substance. The innermost, and even the middle layers, however, may be altogether wanting. Thus, in *Phyllosoma* (Glass-crab) the envelope is formed of the transparent horny layer alone; and in many of the small Crabs belonging to the genus *Portuna*, the whole substance of the carapace beneath the horny investment is made up of hexagonal thick-walled cells. It is in the large thick-shelled Crabs that we find the three layers most differentiated. Thus, in the common *Cancer pagurus* we may easily separate the structureless horny covering after a short maceration in dilute acid; the cellular layer, in which the pigmentary matter of the coloured parts of the shell is contained, may then be brought into view by grinding away as flat a piece as can be selected from the *inner* side (having first cemented the outer surface to the glass slide), and by examining this with a magnifying power of 250 diameters, driving a strong light through it; whilst the tubular structure of the thick inner layer may be readily demonstrated by means of sections parallel and perpendicular to its surface. This structure, which very strongly resembles dentine, save that the tubuli do not branch, but remain of the same size through their whole course, may be particularly well seen in the black extremity of the claw, which is much denser than the rest of the shell, the former having almost the semitransparency of ivory, whilst the latter has a chalky opacity. In a transverse section of the claw, the tubuli may be seen to radiate from the central cavity towards the surface, so as very strongly to resemble their radiation in a tooth; and the resemblance is still further increased by the presence, at tolerably regular intervals, of minute sinuosities corresponding with the laminations of the shell, which seem, like the secondary curvatures of the dentinal tubuli, to indicate successive stages in the calcification of the animal basis. This inner layer rises up, through the pigmentary layer of the Crab's shell, in little papillary elevations; and it is from the deficiency of the pigmentary layer at these parts that the coloured portion of the shell derives its minutely speckled appearance. Many departures from this type are presented by the different species of Crustacea. Thus, in the Prawns there are large stellate pigment-cells, the colours of which are often in remarkable conformity with those of the rock-pools frequented by these creatures; whilst in the Shrimps there is seldom any very distinct trace of the cellular layer, and the calcareous portion of the skeleton is disposed in the form of concentric rings, an approach to which arrangement is seen in the papillæ of the surface of the deepest layer in the Crab's shell.

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* Microscopic Journal.

(1039.) The singular power of breaking off their own limbs, alluded to in paragraph 1037, is possessed by many Crustacea, and is a very indispensable provision in their economy. We have already found the blood-vessels of these animals to be of a delicate structure; and the veins being wide sinuses whose walls possess little contractility, the fracture of a limb would inevitably produce an abundant and speedily fatal hæmorrhage were there not some contrivance to remedy the otherwise unavoidable results of such a catastrophe. Should the claw of a Lobster, for example, be accidentally damaged by accidents to which creatures encased in such brittle armour must be perpetually exposed, the animal at once breaks off the injured member at a particular part, namely, at a point in the second piece from the body; and by this operation, which seems to produce no pain, the bleeding is effectually stanched*.

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* Mr. Spence Bate gives the following account of this remarkable process:—"When a limb is injured, all Crustaceans have the power of rejecting it, except the wound be below the last joint. This is done by a violent muscular contraction, finishing with a blow from another limb, or against some foreign body. The amputation is the work of a few seconds, except when they have but recently cast their exuviæ; at such times the wounded limb will sometimes remain for half an hour or longer before it is rejected.

"The new limb is formed within the shell, where it lies folded up until the next moult, when it appears as a part of the new skeleton, the sac-like membrane which protected it being cast off with the old shell; and the restored member is larger or smaller, in accordance with the length of time which may exist between the amputation of the limb and the shedding of the skin. The condition in which the limb is at that time remains permanent until the next moult, when the whole

(1040.) But the most remarkable part of the phenomenon remains to be noticed:—After this extraordinary amputation has been effected, another leg begins to sprout from the stump, which soon grows to be an efficient substitute for the lost extremity, and gradually, though slowly, acquires the pristine form and dimensions of its predecessor. A beautiful example of this curious mode of reproducing a lost organ is preserved in the Museum of Comparative Anatomy in King's College, London, in which the new limb (one of the cheliferous claws) has already attained the form of the old *chela*, but still remains soft and uncovered by calcareous integument. The process of reproduction is as follows:—The broken extremity of the second joint skins over, and presents a smooth vascular membrane, at first flat, but soon becoming conical as the limb begins to grow. As the growth advances, the shape of the new member becomes apparent, and constrictions appear, indicating the position of the articulation; but the whole remains unprotected by any hard covering until the next change of shell, after which it appears in a proper case,—being, however, still considerably smaller than the corresponding claw on the opposite side of the body, although equally perfect in all its parts.

(1041.) Mr. H. D. S. Goodsir has shown* that in the Lobster this regenerative faculty does not reside at any part of the claw indifferently, but in a special locality, situated at the basal end of the first joint of each of the legs. This joint is almost filled by a mass of nucleated cells surrounded by a fibrous and vascular band; and other nucleated cells intervene between this vascular band and the outer crust. The vessels of the band pass onwards for about half an inch, and return upon themselves, forming loops. When a claw is broken, or otherwise injured or disabled, the Lobster, or Crab, by a violent muscular effort casts it off at the transverse ciliated chink, or groove, which indents the reproductive segment. The new claw is developed by the multiplication of cells, which soon become divided into five groups, answering to the five joints of the future limb; these nascent joints are folded upon each other in the Crab, but extended in the Lobster; in both, they are at first enveloped in a sac formed by the distended cicatrix; the budding limb ultimately bursts this cicatrix, and its growth is rapidly completed. A great proportion of the reproductive cells contained in the basal extremity of the injured limb is made use of in the production of the new limb; but a mass of them is retained unchanged at the basal joint, and is ready to renew the reproductive process when needed. In the lower Crustaceans such groups of cells are found at more numerous joints.

(1042.) The observations made in a former chapter relative to the organs by which the senses of *touch*, *taste*, and *smell* are exercised in

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creature again advances in size, but the new limb more rapidly than the remainder of the animal, until it attains its full relative proportions."—Ann. and Mag. Nat. Hist. 1851, vol. vii. p. 300.

[*] *Vide* Owen on Parthenogenesis, p. 48.

insects, are equally applicable to the animals composing the class before us; for in the Crustacea, although we are compelled to admit the possession of the above faculties, we are utterly ignorant of the mode in which they are exercised; therefore it would be only an unprofitable waste of time to enter at any length into a discussion from which no satisfactory conclusions are, in the present state of our knowledge, to be deduced.

(1043.) The eyes of Crustaceans are of three kinds—*simple, agglomerated*, and *compound.*

(1044.) The simple eyes (*ocelli, stemmata*) resemble those of Spiders, and, like them, are said to consist of a cornea, a spherical lens, a gelatinous vitreous humour, a retina, and deeply-coloured choroid, all occupying their usual relative positions. These eyes never exceed two or three in number.

(1045.) In the agglomerated eyes, such as those of *Daphnia* (fig. 212), the organ seems to be composed of a number of simple eyes placed behind one common cornea; such eyes are moveable; and in the animal depicted in the figure, the muscles acting upon the visual apparatus, which in this case is single, are arranged so as to form a cone, the base of which is formed by the eye, and may be distinctly seen under a good microscope.

(1046.) The compound eyes appear to be constructed upon the same principles as those of insects. The corneæ are extremely numerous, and in general hexagonal; but sometimes, as in the Lobster, they are square. The vitreous humours equal the corneæ in number, and behind each of these a distinct retina would seem to be expanded. The compound eyes of Crustaceans have not, however, as yet been examined with the same patient diligence as those of the Cockchafer; so that, as relates to their minute anatomy, much is still left to conjecture and uncertainty. One peculiarity connected with these organs is, that in the two highest orders of Crustacea, hence called *Podophthalmia*, the eyes are placed at the extremity of moveable pedicles articulated with the first cephalic ring of the external skeleton, and thus they may be turned in various directions without moving the whole body at the samo time. This provision was not required in insects, owing to the mobility of the head in those animals, but is absolutely indispensable in the case before us, where, the head and thorax being consolidated into one mass, the extent of vision commanded by sessile eyes would have been exceedingly limited, and inadequate to the security of creatures exposed to such innumerable enemies.

(1047.) It is in the higher Crustacea that we, for the first time, indubitably find a distinct auditory apparatus; and, from the simplicity which tho organ of hearing presents in this its earliest appearance, an inquiry concerning its structure becomes of great physiological interest. In the Lobster the ears are situated upon the under surface of the basal joints of the second pair of antennæ. On looking carefully, in this situation the student will find a prominent tubercle formed by the shell, the top of which is perforated by a small circular opening covered with a tense membrane. Behind this orifice is placed a minute vesicle filled with fluid, upon which a delicate branch of the antennary nerve is distributed. This constitutes the whole apparatus: the vibration of the water strikes upon the external membrane, the water in the sacculus participates in the tremor, and the expanded nerve conveys to the brain the sensation thus produced.

(1048.) The function of this organ in the Lobster is contested by Dr. Arthur Farre, who observes that it is situated not far from the mouth, and is directed downwards; it is by far the most sensitive part of the body, since, while the mechanical irritation of any other parts excites only slight movements in the limbs of the animal, the touching of this part is immediately followed by violent and almost spasmodic flappings of the tail. These circumstances, together with the situation of the organ, appear to Dr. Farre to point it out as intended possibly for the purpose of testing the quality of the food—as, in fact, an organ of smell, evidently endowed with an exquisite sensibility*. This, however, is evidently merely a matter of conjecture, more especially as in the generality of the Crustaceans such an apparatus is altogether wanting.

(1049.) The true organ of hearing, according to Dr. Farre, is situated in the base or first joint of the lesser pair of antennæ—its precise seat being indicated externally by a tough membrane, which covers an oval aperture in the upper surface of this joint. Towards the inner and anterior margin of this membrane there exists a small round aperture, into which a bristle can be easily passed. On removing the membrane, together with a portion of the surrounding shell, the internal organ is brought into view, completely imbedded in the muscular structure of the antennæ.

(1050.) This organ, the vestibular sac, nearly fills the cavity of the joint, is somewhat sacciform in its shape; and its walls present a delicate horny structure of the consistence of a thin quill, being so transparent as to admit of its contents being seen through the parietes. These are found to consist of numerous minute particles of siliceous sand, which are loosely contained in the interior of the sacculus. The walls of the vestibular sac are furnished with several rows of minute ciliated processes which, when highly magnified, are seen to be hollow and to be covered with a fine down of hairs of exquisite delicacy, while in their interior are contained numerous minute granules, which are apparently nerve-granules. These processes are dilated at their base so as to form a globular swelling, where they are articulated to corresponding circular apertures in the walls of the sac, from which they spring in immediate apposition with a plexus of the auditory nerve, which has a separate and distinct origin from the supra-œsophageal ganglion.

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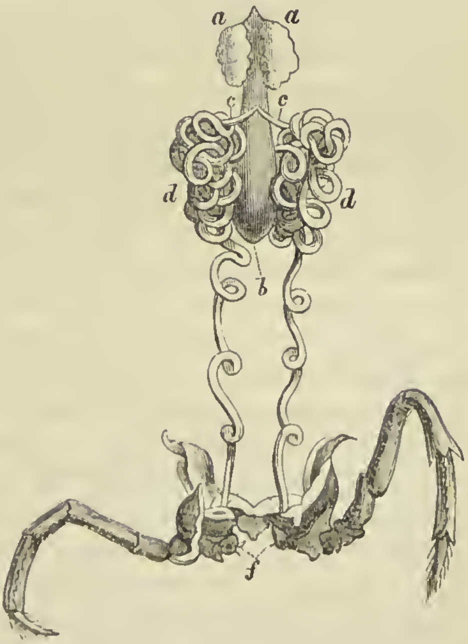
* "On the Organ of Hearing in Crustaceans," by Dr. Arthur Farre, Phil. Trans. 1843, p. 234.

(1051.) The existence of this singularly-constructed apparatus is by no means universal even among the Macrourous Decapods, and in the Brachyura it seems to be altogether wanting. We recognize, however, in its structure all the essential parts of an organ of hearing in its primitive form, viz. a distinct acoustic nerve, terminating in a plexus, which is expanded upon a vestibular sac. The remarkable arrangement of ciliated processes immediately overlying this plexus, with each process filled with nerve-granules, exhibits an apparatus for extending the extremities of the nerves in such a manner as to render them sensitive to the most delicate vibration of the fluid with which the sac is filled. But to heighten the effect of this, the grains of sand are added, thus forming adventitious otoliths, which, moving freely in the fluid contents of the sac, doubtless considerably increase the vibration of that fluid.

(1052.) In the *Brachyura*, or Crabs, the membrane covering the external orifice of the ear is converted into a moveable calcareous lamella, from which, in some genera, a furcate process is continued internally; so that the whole, when removed by maceration, has no very distant resemblance to the *stapes* of the human ear, and, like it, seems to be acted upon by muscular fasciculi, so disposed as to regulate the tension of the vibratile membrane, and thus adapt it to receive impressions of variable intensity.

Fig. 207.



Male generative apparatus of *Astacus fluviatilis*: *a a*, *b*, testicular mass; *c c*, vasa deferentia, forming by their convolutions a kind of epididymus, *d d*; *f*, their external orifices.

(1053.) One of the first circumstances calculated to attract the notice of the anatomist who turns his attention to the structure of the generative system, both in male and female Decapod Crustacea, is the complete separation which exists between the organs belonging to the two sides of the body; for not only are the internal secreting viscera for the most part perfectly distinct from each other, but even the external sexual orifices are equally separate and unconnected.

(1054.) Beginning with the parts observable in the male, we will take the Cray-fish (*Astacus fluviatilis*) as a standard of comparison, and briefly notice the principal variations from the type of structure observable in that species which are met with in other genera.

(1055.) In the Cray-fish, and also in the Lobster, the secerning organs or testes, when examined *in situ*, are found to occupy the dorsal region of the thorax, lying upon the posterior part of the stomach.

(1056.) Examined superficially, the testes would seem to form but one mass, consisting of three lobes (fig. 207, *a a*, *b*); but on investigating the minute structure of the organ, it is found to be made up of very delicate secreting-tubes that give origin to two excretory ducts (*c c*). After numerous convolutions, which form a kind of epididymus (*d*), each duct, becoming slightly dilated, terminates by a distinct orifice (*f*), seen upon the basal articulations of the last pair of ambulatory legs. There is no intromittent apparatus visible; but, according to Milne-Edwards*, the extremity of the excretory duct, by undergoing a kind of tumefaction, may be protruded externally, so as to become efficient in directing the course of the fecundating fluid.

(1057.) In Crabs, the mass of the testis is exceedingly large, but in its essential structure similar to that of the Cray-fish, and the external opening of its excretory duct is found to occupy the same situation; in some genera, however, instead of being placed upon the first joint of the last pair of legs, the orifices of the male organs are found upon the abdominal surface of the last thoracic ring itself.

(1058.) In the male *Brachyura*† the so-called false feet constitute the external sexual organs; and Mr. Bate has several times taken *Carcinus mænas* in the act of copulation, under which circumstances he distinctly saw these styliform processes inserted within the vulvæ of the female. These false feet consist of two pairs, the larger being anterior, and attached to the first abdominal ring,—the less, or posterior, to the second ring. In all, except the edible Crab, the second pair is very small, apparently rudimentary, and lie with their extremities inserted posteriorly into the larger pair. But in *Cancer pagurus*, though slight, they are equally long with the first pair, and have a joint, peculiar to this Crab, situated near their centre, in addition to one, common to others, attached to the basal joint. The orifice of this pair is slightly frilled: it lies posteriorly against the first pair, which are the most important. These latter are styliform, and attached by a hinge to a calcareous continuation of the dermal membrane of the abdomen. From the first joint of the fifth pair of legs a membranous tube (the *vas deferens*) passes out and enters at the second joint of the so-called false feet, continuing through, and terminating at the apex in an oval slit. Internally the tube is derived immediately from the testicle.

(1059.) Mr. C. Spence Bate believes that Crabs have more than one brood to a single impregnation by the male, and that the male can only impregnate the female immediately after the shedding of the exuviæ. "For days previously the male may be seen running about and hiding himself under stones, holding the female by one or more of his legs, the carapace being pressed against the sternum of the male. In this relative position they continue until the female throws off her calcareous clothing, when connexion immediately follows, and continues perhaps for a day or two."

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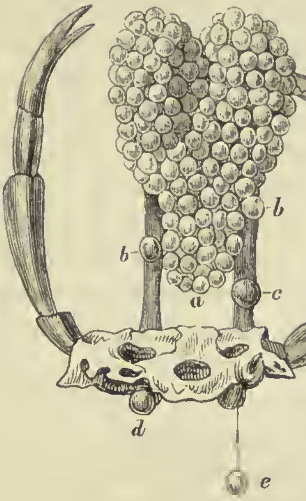
* Cyclop. of Anat. and Phys., art. "CRUSTACEA."

† "Notes on Crustacea," by C. Spence Bate, Ann.&Mag. Nat. Hist., 2 ser. vi. p. 109.

(1060.) The female generative organs of Crustacea very accurately resemble those of the male; and in the unimpregnated condition it is not always easy, from a superficial survey of the internal viscera, to determine the sex. In *Astacus fluviatilis,* the ovaria (fig. 208, *a*) occupy a position analogous to that of the male testis, and a simple canal derived from each side (*b*, *c*) conducts the eggs to the external apertures found upon the first joint of the third pair of legs.

Fig. 208.



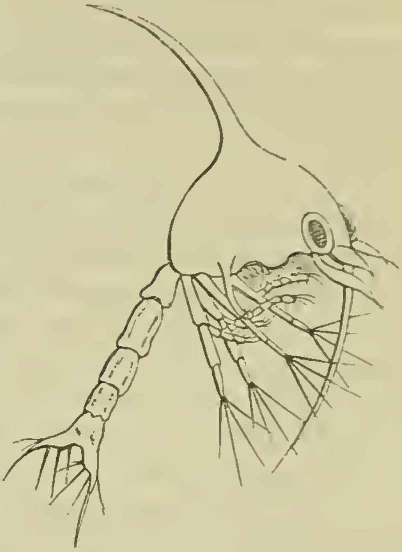
Female generative organs of *Astacus fluviatilis*: *a*, *b b*, ovaria; *c*, oviduct; *d*, external termination of the right oviduct; *e*, escaped ovum.

(1061.) In Crabs, an important addition is made to the female generative system:—prior to the termination of each oviduct it is found to communicate with a wide sacculus, the function of which is apparently analogous to that of the *spermatheca* of insects (§ 886), inasmuch as it seems to form a receptacle for the fecundating secretion of the male, in which the seminal fluid remains, ready to impregnate the ova as they successively pass its orifice during their expulsion from the body.

(1062.) The eggs are almost invariably carried about by the female until they are hatched, and in order to effect this, various means are provided. In the Decapoda they are fastened by a stringy secretion to the false feet under the abdomen; and a female Crab may generally be readily distinguished from a male of the same species by the greater proportionate size of this part of their body.

(1063.) Many of the Decapod Crustaceans, as, for example, the Crayfish (*Astacus fluviatilis*), do not not seem to undergo material alterations of form, but simply moult at certain intervals, throwing off their old integument and acquiring a new covering. Nevertheless, even in the Decapoda it is certain that great metamorphoses take place in the external appearance of the young animals. Cavolini long since announced that the embryo of *Cancer depressus* exhibited at birth a singular and uncouth appearance, of which he gave a very tolerable representation*; and Mr. Thompson has rendered it certain that, even in the development of the common Crab, so different is the outward form of the newly-hatched embryo from that of the adult, that the former has been described as a distinct species, and even grouped among the ENTOMOSTRACA, under the name of *Zoea pelagica*. On leaving the egg, the young Crab presents a curious and grotesque figure (fig. 209): its body is hemispherical, and its back prolonged upwards into a horn-like appendage; the feet are scarcely visible, with the exception of the last two pairs, which are ciliated like those of a Branchiopod, and formed for swimming. The tail is longer than the body, possesses no false feet, and the terminal joint is crescent-shaped and covered with long spines. The eyes are very large, and a long beak projects from the lower surface of the head.

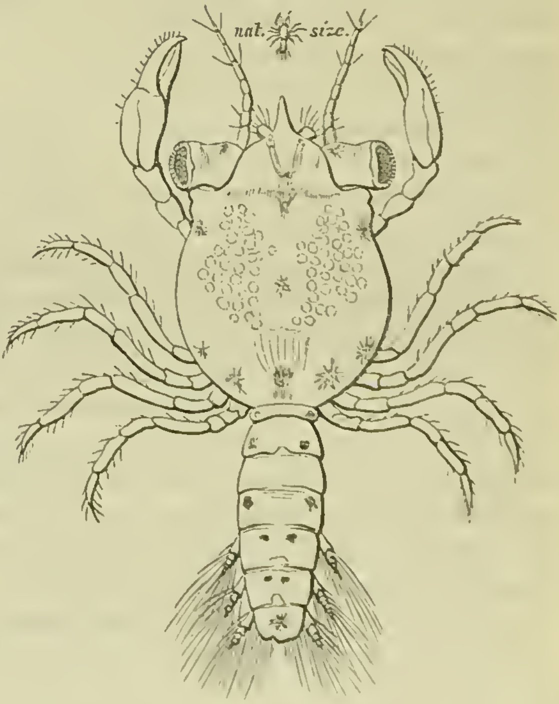
Fig. 209.



Metamorphosis of Crab.

(1064.) In a more advanced stage of growth the creature assumes a totally different shape (fig. 210), under which form it has been known to naturalists by the name of *Megalopa*. The eyes become pedunculated, the cephalothorax rounded, the tail flat and provided with false feet, and the chelæ and ambulatory extremities well developed.

Fig. 210.



Metamorphosis of Crab.

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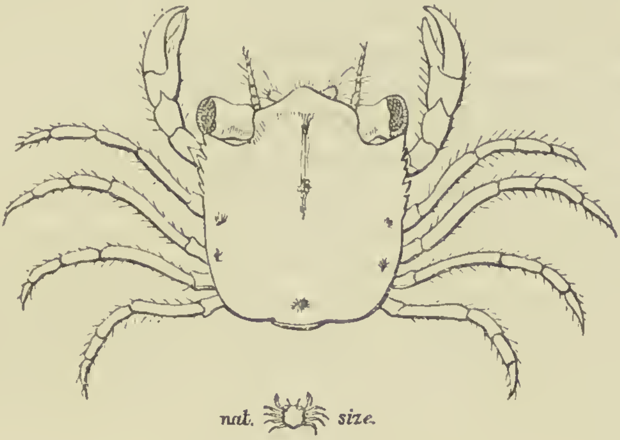
* Sulla Generazione dei Pesci e dei Granchi. 4to. Naples, 1787.

(1065.) A subsequent moult gives it the appearance of a perfect Crab; and then only does the abdomen become folded under the thorax, and the normal form of the species recognizable (fig. 211).

Fig. 211.



Metamorphosis of Crab.

(1066.) Notwithstanding the diversity of form under which the young Crab presents itself at different phases of its growth, examples of which we have here figured, it would seem, from the observations of Mr. C. Spence Bate*, that the progress made towards the mature condition is not by any sudden metamorphosis, but by a series of moultings similar to those which take place in the adult, and that with each successive moult there is a corresponding degree of progress in its development. But the amount of change at each moult is so little that it gives to the animal but a very small degree of difference in its general appearance; and it is only by a comparison of the earliest form with the last, and that without any consideration of the intermediate stages in its growth, that the idea of a true metamorphosis in Decapod Crustacea has arisen. There are, in fact, six or seven well-marked stages or forms that the growing animal passes through in its progress to maturity; and each of these is linked to the preceding as well as to that which follows by a succession of changes that are but just appreciable.

(1067.) Branchiopoda.—In the *Branchiopod* Crustacea (so called from this circumstance), the legs used in swimming would appear to be converted into broad-fringed lamellæ, so thin that they perform the office of branchiæ, and render needless the existence of other instruments of respiration. In *Daphnia,* for example (fig. 212), a creature common in every stagnant pool, the body is contained, as it were, between two corneous plates, open along their inferior edge. Through this transparent envelope the legs may be perceived in constant movement; and from the extreme delicacy of the covering that invests them, they evidently present to the surrounding medium a surface of sufficient extent for the purpose of exposing the blood to its action, thus rendering them efficient substitutes for branchiæ, while, at the same time, their movements ensure a perpetual renovation of the water in contact with them; so that, as a necessary consequence, the respiratory process will be accomplished with greater completeness in proportion as the exertions of the animal become more vigorous. In the Crustacea, indeed, we have many interesting and beautiful examples of the connexion between the respiratory and locomotive organs. The amount of respiration must necessarily be equivalent to the expenditure of muscular energy; and a more elegant manner of ensuring an exact correspondence between the one and the other, than that adopted, could scarcely be imagined; for, by appending the branchiæ to the locomotive agents themselves, the more actively the latter are employed, the more freely will the former receive the influences of the aërated water in which they are immersed.

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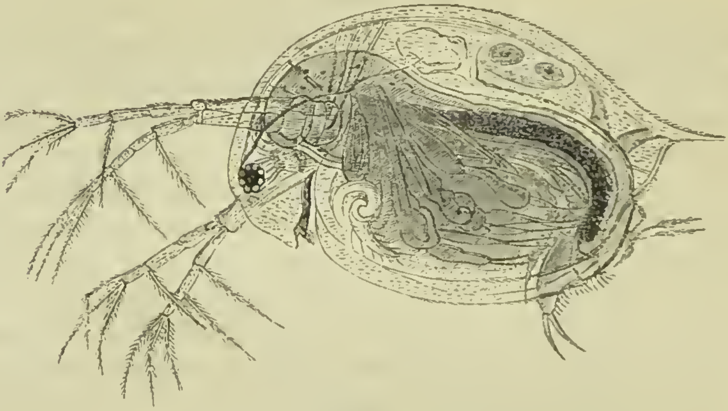
* Phil. Trans. 1848.

Fig. 212.



Daphnia.

(1068.) In the *Squilla*, which swims by means of the movements of its broad tail, it is the false feet beneath the abdominal segments that become branchial organs; and these, being expanded into broad and vascular lamellæ, perform the office of gills. In the *Squilla*, therefore, and similarly-formed genera, the free movement of the tail ensures the full and complete exposure of the respiratory structures to the surrounding element.

(1069.) The more minute Branchiopods, or *Entomostraca*, as they are called by zoologists, offer, in their mode of reproduction, several remarkable variations from what has been described above; and a brief account of their most interesting peculiarities is therefore still wanting to complete this part of our subject. These little creatures, in fact, seem to form a transition between the class we are now considering and the EPIZOA, which many of them resemble so nearly, that they are still confounded together by many authors. The female Entomostraca frequently carry their ova in two transparent sacculi attached to the hinder part of the body; and it is in these egg-bags that the oviducts terminate; so that the ova, as they are formed, are expelled into the singular receptacles thus provided. Without such a provision, indeed, it would be difficult to conceive how the ova could possibly remain attached to the parent, as they far surpass in their aggregate bulk the size of her entire body, and therefore could not by any contrivance be developed internally without bursting the crustaceous covering that invests the mother. Jurine*, Ramdohr†, and other authors have carefully watched the generative process in several genera, and brought to light many important and curious facts connected therewith. In *Cyclops*, a species to be met with in every ditch, the impregnation of the ova is undoubtedly effected in the body of the parent; and the eggs, when formed, are expelled into two oval sacs placed on each side of the tail, which Jurine calls *external ovaries*. The number of eggs contained in these sacs gradually increases; and they exhibit a brown or deep-red colour until a short period before the growth of the embryo is completed, when they become more transparent. In about ten days the eggs are hatched and the young escape; and such is the prodigious fertility of these little beings that a single female will, in the course of three months, produce ten successive families, each consisting of from thirty to forty young ones.

(1070.) In the genus *Apus*, another plan is resorted to for the protection of the ova:—the eleventh pair of legs, called by Schäffer "womb-legs," have their first joints expanded into two circular valves, which shut together like a bivalve shell, and thus form a receptacle in which the eggs are contained until they arrive at maturity.

(1071.) In *Daphnia* (fig. 212), the ovaria are easily distinguished through the exquisitely transparent shell, especially when in a gravid state; and the eggs, after extrusion, are lodged in a cavity situated between the shell and the exterior of the body, where they remain until the embryo attains its full growth.

(1072.) One fact connected with the reproduction of the Entomostraca is so remarkable, that, had we not already had an instance of the occurrence of a similar phenomenon in the insect world (*Aphides*), the enunciation of it would cause no little surprise to the reader; and had its reality been less firmly substantiated by the concurrent testimony of numerous observers who have witnessed it in many different genera (*Cyclops*, *Daphnia*, &c.), it might still be admitted with suspicion. In the genera above mentioned, it has been ascertained, by careful experiments, that a single intercourse between the sexes is sufficient to render fertile the eggs of several (at least six, according to Jurine) distinct and successive generations.

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* Histoire des Monocles. 1 vol. 4to. Genève, 1820.

† Matériaux pour l'Histoire de quelques Monocles allemands. 4to. 1805.

(1073.) In many species there is a double mode of reproduction, the sexual and the non-sexual. The former takes place at certain seasons only, the males disappearing entirely at other times; while the latter continues at all periods of the year, so long as warmth and food are supplied, and is repeated many times, so as to give origin to many successive broods. Further, a single act of impregnation serves to fertilize not merely the ova which are then mature, or nearly so, but all those subsequently deposited by the same female, even at considerable intervals. In these two modes the multiplication of these little creatures is carried on with great rapidity, the young animal speedily coming to maturity and beginning to propagate, so that, according to the computation of Jurine, founded upon data ascertained by actual observation, a single fertilized female of the common Cyclops might be the progenitor of 4,442,189,120 young.

(1074.) The eggs of some Entomostraca are deposited free in the water, or are carefully affixed in clusters to aquatic plants; but they are more frequently carried for some time in special receptacles developed from the posterior part of the body, and in many instances they are retained there until the young are ready to come forth. In *Daphnia* the eggs are received into a large cavity between the back of the animal and the shell, and there the young undergo almost their whole development. Soon after their birth a moult or exuviation takes place, and the egg-coverings are got rid of with the cast shell. In a very short time afterwards another brood of eggs is seen in the cavity, and the same process is repeated. At certain times, however, the Daphnia may be seen with a dark opake substance within the back of the shell, which has been called the *ephippium*, from its resemblance to a saddle. This, when carefully examined, is found to be of dense texture, and to be composed of a mass of hexagonal cells; and it contains two oval bodies, each consisting of an ovum covered with a dense horny casing, enveloped in a capsule, which opens like a bivalve shell. From the recent observations of Mr. Lubbock*, it appears that the ephippium is really only an altered part of the carapace, its outer walls being a part of the outer layer of the epidermis, and its inner valve the corresponding part of the inner layer. The development of the ephippial eggs takes place at the posterior part of the ovaries, and is accompanied by the formation of a greenish-brown mass of granules; from this situation the eggs pass into the receptacle formed by the new carapace, where they become included between the two layers of the ephippium. This is cast, in process of time, with the rest of the skin, from which, however, it soon becomes detached, and continues to envelope the eggs, generally floating on the surface of the water until they are hatched with the returning warmth of spring. This curious provision is obviously destined to afford protection to the eggs which are to endure the severity of the winter's cold. There seems a strong probability, from the observations of Mr. Lubbock, that the ephippial eggs are true sexual products, since males are to be found at the time when the ephippia are developed, whilst it is certain that the ordinary eggs can be produced non-sexually, and that the young that spring from them can reproduce their race in like manner. It has been ascertained by Dr. Baird that the young produced from the ephippial eggs have the same power of continuing the race by non-sexual reproduction as the young developed under ordinary circumstances. In most Entomostraca, the young, when first hatched, have only the thoracic portion of the body as yet developed, and possess but a small number of locomotive organs. The eyes, too, are at first frequently wanting. The process of development goes on with great rapidity, the animal at each successive moult (which process takes place at intervals of a day or two) presenting some new parts and becoming more and more like its parent,—the females laying eggs before they have acquired their full size.

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* Proc. of Roy. Soc., Jan. 29, 1857.

(1075.) The cast shell carries with it the sheaths not only of the limbs and plumes, but of the most delicate hairs and setæ connected with them. If the animal have previously sustained the loss of a member, it is gradually renewed at the next moult, as in the higher Crustacea.

(1076.) Some authors have supposed, from the circumstance of all the individuals which have been met with belonging to certain genera being females, that some of these little beings were hermaphrodite, or self-impregnating; but such an opinion rests on very doubtful grounds, especially as there seems good reason to believe that in many instances the forms of the male and female of the same species are so different that they might easily be mistaken for totally distinct animals.

(1077.) The last point which we have to notice, in connexion with the history of the Crustacea, is the progress of their development from the embryo condition to the mature state. This is a subject which has given rise to considerable discussion, especially as relates to the changes which occur during the growth of the more highly organized forms,—some authors contending that they leave the egg complete in all their parts and presenting their adult configuration, while others assert that they undergo changes so important as only to be comparable with the metamorphoses of insects.

(1078.) Among the Entomostraca such changes have been again and again witnessed, and the appearances observed during their growth carefully recorded. From these observations very important results have been obtained, inasmuch as many forms previously described as distinct species have been found to be merely the same animal in different stages of development. In *Cyclops*, for example, the newly-hatched embryo possesses only four legs, and its body is round, having as yet no appearance of caudal appendages: of young animals in this condition Müller had formed a distinct genus, *Anymene**; in about a fortnight they get another pair of legs, and form the genus *Nauplius* of the same author.

Fig. 213.

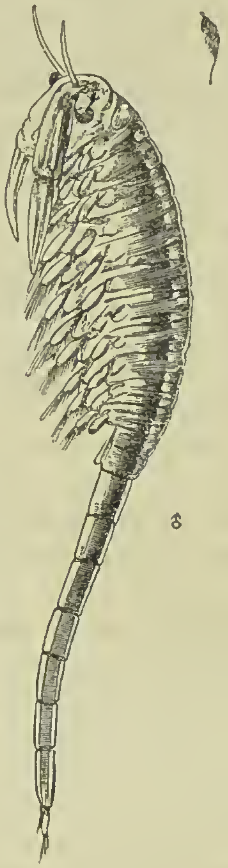
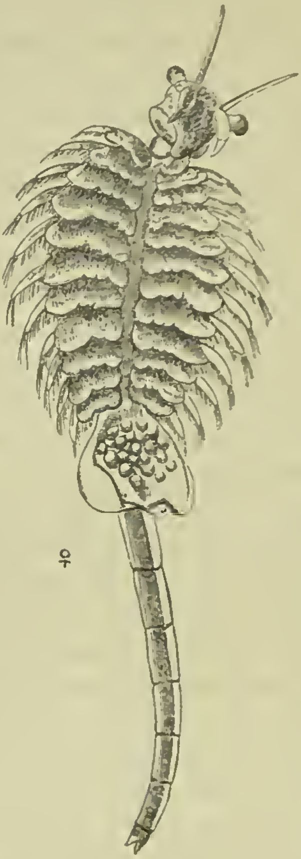
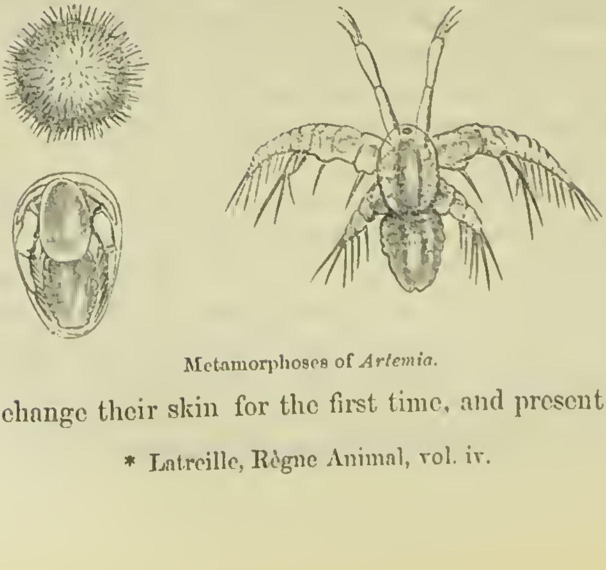


Fig. 214.



Artemia salinus.

Fig. 215.



Metamorphoses of *Artemia*.

They then change their skin for the first time, and present the form of the adult, but with antennæ and feet smaller and more slender than in the perfectly mature state. After two other changes of skin they become capable of reproduction.

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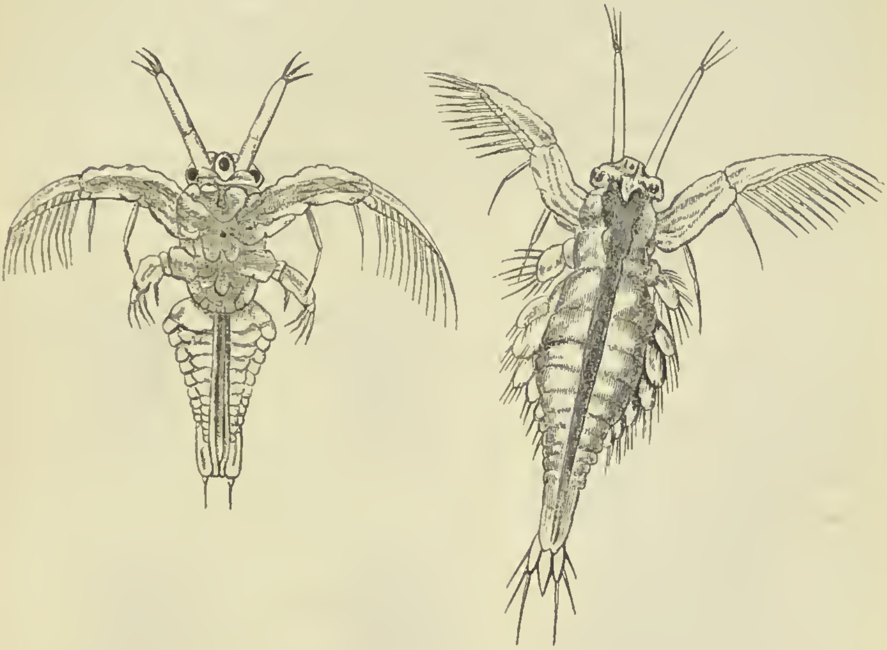
* Latreille, Règne Animal, vol. iv.

Fig. 216. Fig. 217.



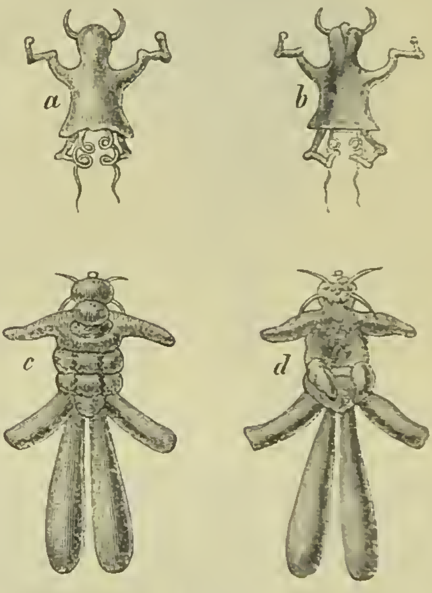
Metamorphoses of *Artemia.*

(1079.) The Salt-marsh Shrimp (*Artemia salinus*) affords a good example of these remarkable exuviations. This animal is especially interesting, as being, perhaps, the nearest approach in existing nature to the extinct forms of *Trilobites* so abundantly met with in certain geological strata ; and we have accordingly given, upon an enlarged scale, accurate drawings of its external organization, both in the male and female (figs. 213 & 214). Who, however, would recognize, in the embryo of this Crustacean on its first quitting the egg (fig. 215), any resemblance to the adult creature, or even, in its second condition (figs. 216 & 217), be able to identify it as belonging to the same species as that depicted above—so completely are all its parts remodelled in their structure before arriving at the mature state?

(1080.) Epizoa.—An extensive group of animals closely resembling the Crustaceans have been so constructed as to be capable of attaching themselves to the external parts of other creatures, from which they suck the nourishment suited to their nature.

(1081.) These parasites are commonly found to infest fishes and other inhabitants of fresh and salt water, generally fixing themselves in positions where an abundant supply of animal juices can be readily obtained, and where, at the same time, the water in which they are immersed is perpetually renewed for the purpose of respiration. The gills of fishes, therefore, offer an eligible situation for their development, as do the branchiæ of other animals; or they are sometimes found attached in great numbers to the interior of the mouth in various fishes, deriving from its vascular lining, or from the abundant secretions met with in such a locality, a plentiful supply of food, while they are freely exposed to the currents of water which the mode of respiration in the fish brings in contact with them.

Fig. 218.



Lerneans.

(1082.) The least-elaborately organized of these animals exhibit exceedingly grotesque and singular shapes, resembling imperfect embryos rather than mature beings,—the first buddings of external limbs, in the earlier period of fœtal development, imitating not very remotely the appearance of the rudimentary appendages represented in the annexed figure* (fig. 218).

(1083.) A great number of species of these parasites, generally described under the name of *Lerneans*, have been observed by authors, and it would seem, moreover, that each is peculiar to a particular kind of fish. The variety exhibited in their outward forms is, of course, exceedingly great; but the examples depicted in the figure, namely the *Lernæa gobina*, found in the branchiæ of *Cottus Gobio*, and *Lernæa radiata*, which infests the mouth of *Coryphæna rupestris*, will make the reader sufficiently acquainted with their general appearance and external structure. In the former parasite, of which a posterior and an anterior view are given in fig. 218 (*a*, *b*), the appendages seen upon the head and sides of the body answer the purpose of hooks or grappling organs, whereby the creature retains its position; and so firm is its hold upon the delicate covering of the gills, that, even after the death of the fish, it is not easily detached. In the second example (*c*, *d*), besides the rudimentary limbs, the lower surface of the head and ventral aspect of the body (*d*) are covered with sharp spines, calculated to increase very materially the tenacity of its hold upon the surface from which it imbibes food. The sacculi appended to the posterior part of the animal are receptacles for the eggs and will be explained hereafter.

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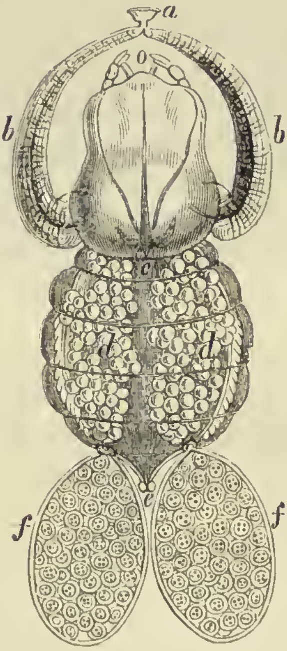
* Müller (O. F.), Zoologia Danica, 1788.

(1084.) These examples, however, are taken from the most imperfectly organized Epizoa; but as we ascend to more highly-developed species, we shall at once see how gradually an approximation is made to the articulated outward skeleton and jointed limbs met with in the Homogangliate forms of being, until at last the zoologist remains in doubt whether the more elaborately-constructed ought not to be admitted among the Crustacean families which they most resemble.

(1085.) The *Achtheres Percarum* (fig. 219) is one of those species most nearly allied to the Articulata; and the details of its anatomy having been fully investigated by Nordmann*, it will serve as a good example of the type of structure which prevails throughout the group.

Fig. 219.



Actheres Percarum: *a*, adhesive disk; *b b*, posterior pair of limbs; *c*, stomach; *d d*, ovaria; *e*, anal orifice; *f f*, ovisacs; *o*, antennæ.

(1086.) The *Achtheres* is found to infest the Perch (*Perca fluviatilis*), adhering firmly to the roof of the mouth, to the tongue, or sometimes even to the eyes of that fish, in which situations it is concealed by a brownish slimy secretion, so that its presence might easily escape the notice of a casual observer.

(1087.) The female, represented in the figure, is about 2 lines in length; the male, which differs materially from the other sex in many points, is considerably smaller.

(1088.) The outer covering of the body of these little creatures is at once seen to have assumed a horny hardness approximating to the density of the coverings of the Entomostraca; and indications are even perceptible of a division into segments: the distinction, moreover, between the trunk (*cephalothorax*), to which the limbs are appended, and the abdomen, wherein the viscera are lodged, is obvious.

(1089.) Instead of the rude and imperfect limbs we have seen in the Lerneans, the legs are visibly more perfect in their entire construction; and in the female, the posterior pair of these appendages are converted into a most singular instrument of attachment, whereby the *Achtheres* fixes itself to the gums of the fish. The hinder pair of extremities alluded

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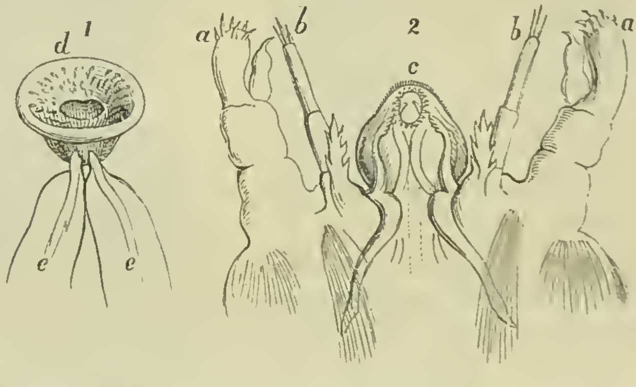
[*] Mikrographische Beiträge zur Naturgeschichte der wirbellosen Thiere. Berlin, 1832.

to (fig. 219, *b b*) are, in fact, enormously developed; they curve forward after their origin from the posterior part of the trunk, and are so much extended that they project considerably beyond the head of the creature, where, becoming considerably attenuated, the two are joined together by a kind of suture, and support, upon the point where they are united, a cup-shaped organ whereby the creature fixes itself. This singular instrument (represented upon an enlarged scale at fig. 220, 1) is of a cartilaginous hardness, resembles a little bowl the inside of which is studded with sharp teeth, and is not only calculated to act as a powerful sucker, but, from the hooks within its cavity, is capable of taking a most tenacious hold upon the lining membrane of the mouth.

(1090.) The other members (fig. 219, *o*) are much less developed, but are nevertheless so constructed as to assist materially in fixing the Epizoon; they are represented upon a very large scale in fig. 220, 2, where the outer pair (*a a*) are seen to exhibit, in the transverse lines indented upon their surface, the first indication of articulated limbs, and their extremities, armed with minute hooks, evidently form powerful agents for prehension. Internal to these are two other jointed organs, still more feeble in their construction, the ends of which (*b b*), being armed with three spines, will assist in effecting the same object.

(1091.) The mouth itself (fig. 220, 2, *c*) is formed upon similar principles, the external orifice being surrounded with a circle of minute recurved spines, well calculated to ensure its firm application to the surface from which nourishment is obtained; and within this, rudimentary jaws furnished with strong teeth are visible, adapted, no doubt, to scarify the part upon which the mouth is placed, in order to ensure an adequate supply of food. In the male *Achtheres*, the sucking-bowl possessed by the female does not exist, the prehensile organs being merely four stout articulated extremities, armed at the end with strong prehensile hooks.

Fig. 220.

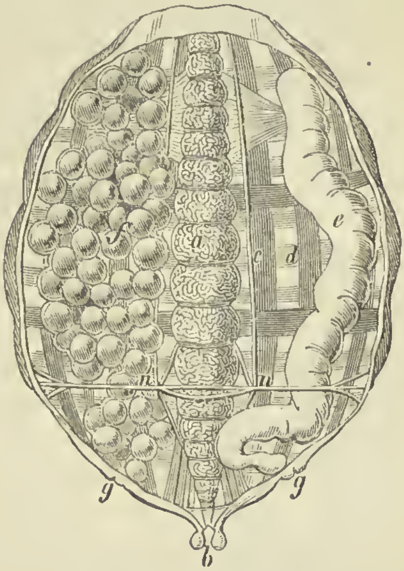


Details of the structure of *Achtheres*. 1. Adhesive disk on an enlarged scale: *e e*, conjoined extremities of the hinder pair of legs. 2. Structure of the mouth and parts adjacent: *a a*, anterior limbs; *b b*, antennæ; *c*, mouth, furnished with rudimentary jaws.

(1092.) As we might suppose, from the nature of the food upon which this creature lives, the alimentary system is extremely simple. The œsophagus (the course of which is represented by dotted lines in the same figure) terminates in a straight digestive canal (fig. 221, *a*), which passes through the centre of the abdomen; but no separation between stomach and intestine is visible. The entire tube, from the transverse constrictions visible upon its surface, has a sacculated appearance, and is perceptibly dilated towards the centre of the abdominal cavity; after which it again diminishes in size as it approaches the anal orifice (*b*), situated at the posterior extremity of the body.

(1093.) Near the termination of its course, the alimentary canal passes through a loop formed by transverse bands (*n n*), and, moreover, seems to be retained in its position by radiating fibres, apparently of a ligamentous character, but which have been described as representing a biliary apparatus.

Fig. 221.



Viscera of *Achtheres Percarum*: *a*, alimentary canal; *b*, anal orifice; *c*, nervous filaments?; *d*, muscular bands; *e*, unimpregnated, and *f*, impregnated ovary; *g g*, external openings of the ovaria.

(1094.) The muscular system of this animal is far more perfect in its arrangement than in the preceding classes, and the delicate fasciculi which move the rudimentary limbs are visible through the transparent integument (fig. 219). In the abdomen, the muscles form longitudinal and transverse bands that intersect each other at right angles (fig. 221, *d*)—an arrangement not very different from what we shall soon meet with in the rotiferous animalcules.

(1095.) The nervous system appears to consist prnicipally of two long filaments (fig. 221, *c*) that run beneath the alimentary canal: but it is extremely probable that these communicate with some minute ganglia in the neighbourhood of the head; at least, the perfect structure of the oral apparatus and the development of the limbs would seem to indicate such a type of structure.

(1096.) The generative organs in the female *Achtheres* consist of two parts—the ovaria, wherein the eggs are formed, contained in the abdominal cavity (fig. 219, *d d*)—and of two external appendages, or egg-sacs (fig. 219, *f f*), which are attached to the posterior extremity of the body, for the purpose of containing the eggs until their complete development is accomplished: this arrangement we have already had an opportunity of examining in the Entomostracous Crustaceans.

(1097.) The internal ovaria (fig. 221, *f*), when distended with ova, occupy a great part of the cavity of the abdomen, and present a racemose appearance; but when empty, as represented upon the opposite side of the same figure (*e*), each is found to be a simple blind canal with sacculated walls, opening externally by an orifice (*g g*) through which the ova are expelled into the egg-sacs, where their development is completed.

(1098.) It would seem that, even when the eggs are hatched, the excluded young are far from having attained their perfect or adult form, but undergo at least two preparatory changes or metamorphoses, during which they become possessed of external organs so totally different from those they were furnished with on leaving the egg, that it would be difficult to imagine them to be merely different states of existence through which the same animal passes.

(1099.) On first quitting the egg, the young *Achtheres* is, in fact, by no means adapted to the parasitical life to which it is subsequently destined—possessing no organs of prehension like those of the adult, but merely two pairs of swimming-feet, each armed with a brush of minute hairs, and calculated to propel it through the water. Before, however, the first change is effected, another set of feet may be perceived through the transparent external covering, encased, as it were, in the first; when these are completely formed, the original skin falls off, displaying, in addition to the two new pairs of swimming-feet, three pairs adapted to prehension; and it is only when the second set of feet is thrown off in a similar manner that the animal assumes its perfect or mature form.

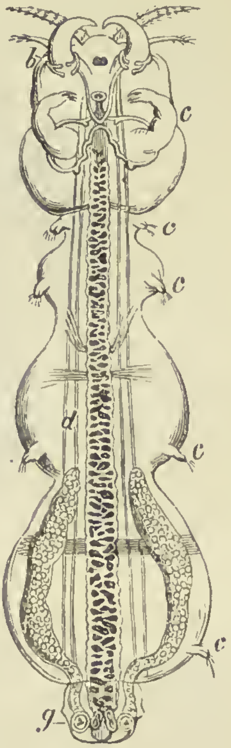
(1100.) In *Lamproglena pulchella* we have a still more decided exemplification of the Crustacean type of structure, and the rudimentary feet, arranged in symmetrical pairs, are as numerous as the segments of the body. The limbs, however, are as yet only adapted to secure a firm hold upon the structures whereunto this parasite attaches itself, namely the gills of the Chub (*Cyprinus Jeses*), in which situation it is most usually found. The two anterior pairs (fig. 222, *b*, *c*) are far more largely developed than those which are placed upon the posterior parts of the animal, and are apparently strengthened by a cruciform cartilaginous framework, seen through the transparent integument. The first pair of these holding-feet consist of two robust and powerful hooks, terminated by simple horny points; whilst the second, which are likewise unciform, terminate in trifid prongs, and are evidently equally adapted to prehension. The four pairs of members that succeed to these are mere rudiments, and can be of little service as organs of attachment; but, to make up for their imperfection, we find at the posterior extremity of the body, between the orifices of the ovaria (*g*), a pair of cartilaginous suckers, well calculated to fix this part of the animal.

(1101.) The muscular system is readily seen through the transparent skin: four longitudinal bands are visible (d), running from one end to the other; and, besides these, broad transverse fasciculi are discernible in the fifth and sixth segments of the body. From the nature of the feet, however, and general structure of the creature, we must imagine the existence of muscles provided for the movements of each articulated member, although, from their extreme minuteness, they escape detection.

(1102.) The opening of the mouth is placed in the centre of the space bounded by the four anterior prehensile hooks; and the alimentary canal is a simple tube passing straight through the body to the tail, where the anal orifice is distinguishable. The walls of the intestine have a reticulated appearance, being covered with a kind of glandular network, that probably constitutes a biliary apparatus.

(1103.) In a creature thus highly organized we may well expect to find senses of proportionate perfection; and in *Lamproglena* their existence is no longer doubtful. The eyes are distinctly apparent, of a reddish colour; but, as yet, as in the lowest Crustaceans, united into one mass. The antennæ likewise, which may be regarded as special instruments of touch, are well developed, and, both in number and position, resemble those that characterize the Crustacean orders, to which we are thus conducted by almost imperceptible gradations.

Fig. 222.

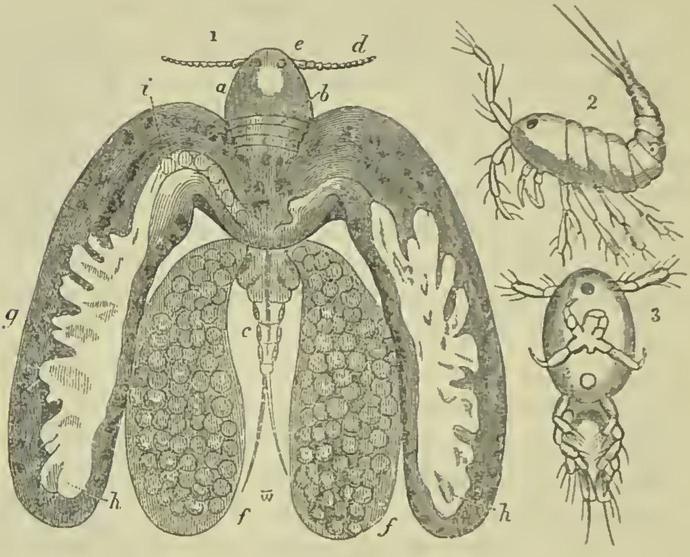


Lamproglena pulchella.

(1104.) The reproductive organs are entirely similar to those of *Achtheres*, already described. Those of the female, represented in the figure, consist of sacciform ovaria, wherein the ova are secreted; and from these, when mature, the eggs are expelled through two simple triangular orifices situated on each side of the anus.

(1105.) One of the most singular and anomalous forms of the Epizoa is found in the *Nicothoë Astaci*, a creature met with in great abundance at certain seasons, attached to the gills of the Lobster, from which it derives its supply of nourishment. This remarkable animal (fig. 223), which is free, and gifted with energetic powers of locomotion during the first periods of its existence, and constructed, at its first appearance from the egg, in perfect accordance with the normal type belonging to its class, ultimately selects for its domicile the branchial chamber of a Lobster, where, fixing itself permanently to the branchial lamellæ, it undergoes a complete metamorphosis: its external form is entirely changed; its senses, and means of relation with the external world, become atrophied; singularly-formed excrescences sprout

Fig. 223.



Nicothoë Astaci.

from its sides; and thus transformed, it is content to live beneath the shell of the Lobster, without further intercourse with the external world than is necessary to supply it with the blood which it sucks for food.

(1106.) The mouth of the *Nicothoë* is a sort of membranous proboscis, armed near its extremity with styliform points, with which it is enabled to pierce the branchial membrane. Instead of the ordinary more or less flexuous tube which constitutes the alimentary canal in other forms of Entomostraca, the digestive apparatus of *Nicothoë* consists of two wide sacculi, united together in the median line, in the shape of a horseshoe, from the centre of which a narrow canal proceeds towards the mouth, constituting the œsophagus (fig. 223, *b*), whilst, derived from the opposite side, another tube of similar calibre runs backwards to the termination of the tail, forming the intestine (*c*). The stomach, therefore, is constituted by the two great lateral cæca (*g*, *h*), in the interior of which alimentary substances undergo their principal modifications; so that these cæca are evidently analogous to what will be observed in the Pycnogonidæ (§ 1112), with this difference, that in those animals the cæca have penetrated into the interior of the ambulatory claws. The thickness of the walls of these stomachal cæca is uniform throughout; they are exceedingly delicate, only exhibiting in their texture some small reddish cells, and are apparently connected to the parietes of the body, in which they are loosely suspended by delicate muscular fræna.

(1107.) One very remarkable circumstance presented by the alimentary apparatus of *Nicothoë* is the peristaltic action of its parietes, which is continued even after its removal from the body, and which here is evidently in relation with the "*phlebenterism*" exhibited in the arrangement of the digestive system. No proper respiratory organs exist in these simply-organized beings; the diffusion of the blood through the interior of the body, subservient alike to respiration and nutrition, seems to be entirely effected by the contractions of the intestinal walls; and the proper chylific viscera themselves perform the duties of the lacteal, circulatory, and respiratory apparatus of the higher animals.

(1108.) As is the case with the generality of the Lerneans, the male of the *Nicothoë* was, until recently, unknown to naturalists—a circumstance attributable to two causes: in the first place, the individuals of the male sex are very diminutive in all the genera belonging to this group, insomuch that from their size they seem rather like parasites on the female; and secondly, because in some of them, which have been more particularly studied, a phenomenon is observable analogous with what occurs in the *Aphides* among insects—there occur whole generations of fertile females, and most probably, also, gemmiparous (nursing) races, during a certain portion of the year, as is the case with *Limnadia** and *Daphnia*† (§ 1072).

(1109.) The male of *Nicothoë* is represented in fig. 223, 2, magnified in the same proportion as the female. The generative apparatus of the female is largely developed: it is situated principally in the lateral appendages of the body, of which it occupies a considerable part, being lodged by the side of the digestive cæca. The ovarium (fig. 223, 1, *h*) is very irregular in its shape; anteriorly it is bifurcate, and its whole surface has a sacculated appearance. The oviducts (*i*) become conjoined near the mesial line, and then bend downwards to terminate at the vulva. These canals are frequently filled with ova throughout their whole length. From the oviducts the eggs pass directly into the enormous ovisacs (*f*), suspended from each side of the caudal portion of the body, between the lateral appendages, in which they are contained until sufficiently mature for exclusion, when the ovisac, bursting, gives issue to hundreds of minute Nicothoës hatched in its interior.

(1110.) On emerging from its prison this little creature is exceedingly active, and presents exactly the form of a *Cyclops* (fig. 223, 3); neither would any one ever suspect it to be the same creature which vegetates upon the branchiæ of the Lobster. However, no sooner has it fixed itself in that situation than its body begins to swell out laterally, in the shape of two tubercles that sprout from the sides of the body just behind the third thoracic segment, into which the viscera are seen to penetrate; and as these tubercles enlarge, the animal becomes gradually provided with those enormous aliform appendages that are so characteristic of the female adult Nicothoë.

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* *Vide* Ad. Brongniart, "Mém. sur le Limnadia," Mém. du Mus. 1820.

† Straus-Durckheim, "Mém. sur le Daphnia," Mém. du Mus. 1820.

(1111.) PYCNOGONIDÆ.—In the Pycnogonidæ*, the aperture of the mouth is found at the extremity of the tubular proboscis which projects from the anterior part of the body of these remarkably-constructed animals, and which, from its general conformation, certainly reminds us more of the Acaridiform Arachnidans than of the Crustacean type of structure. The œsophagus is an extremely delicate and slender canal which passes directly backwards into the cephalothorax, where it at once expands into a central digestive cavity or stomach which occupies the centre of the body, and terminates posteriorly in a very narrow and rudimentary intestine.

(1112.) From the circumference of the stomach are given off ten long cæca, the disposition of which is remarkable: of these, the two anterior are prolonged forwards to the pincer-like rudimentary foot-jaws or palpi, into the interior of which they penetrate for some distance; while the remaining four pairs, which are of great length, are continued in a similar manner into the locomotive or thoracic legs, extending almost to the end of the antepenultimate joint. The anal orifice of the intestine is situated, as usual, at the extremity of the very rudimentary abdomen.

(1113.) When distended with fluid, these cæca may be observed to become constricted opposite to each articulation of the limb. Their structure is exceedingly simple; indeed, they seem to consist of a very thin diaphanous membrane, in which no trace of fibre is distinguishable, but which externally seems to be crusted over with a granular opake substance, sometimes presenting a violet or yellowish tint. These granulations are more thinly scattered over the stomach than over the cæca, and upon the intestine they are wanting altogether. The whole of this digestive apparatus, notwithstanding that its walls contain no perceptible fibres, is contractile, and floats freely in the general cavity of the body, being only retained *in situ* by a few delicate fræna; its different parts may be observed to have alternate movements of contraction and dilatation, driving, in undulations, first in one direction and then in another, the liquid which they contain. This liquid, which is quite transparent, hurries along with the materials in process of digestion. These generally present themselves under the appearance of roundish or ovoid masses, about $\frac{1}{40}$th of a millimetre in diameter, smooth and entirely without granulations during the earlier period of the digestive process: but as digestion advances, they may be seen to become decomposed into roundish granules that powerfully refract the light, and which are scarcely $\frac{1}{300}$th of a millimetre in size. The fæces seen in the intestine are entirely made up of these granules irregularly agglomerated together; and it is rare to find among them any traces of alimentary substances which are not entirely decomposed.

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* *Vide* M. de Quatrefages, Ann. des Sci. Nat. 1844, iv. p. 72.

(1114). It has been stated above, that all that portion of the alimentary canal which intervenes between the œsophagus and the intestine is free, and floating loosely in the general thoracic cavity, which cavity is prolonged into the limbs extending beyond the terminations of the cæca; and in this cavity it is easy to distinguish the muscles subservient to locomotion, and which, more especially in the limbs, line, as it were, all the interior of the different joints, so that the digestive apparatus is evidently lodged in a great *lacuna* or cavity which occupies the entire thorax, and is prolonged into the claws. This *lacuna* is filled up with a transparent fluid, in which may be distinguished a great number of irregular transparent corpuscles, which appear to consist of agglomerations of smaller globules. The fluid is constantly agitated with irregular movements backwards and forwards, which are determined by the general movements of the animal, or by the alternate contractions and dilatations of the stomach and cæca, and which constitute all the circulation which is discernible in these creatures. No organ is detectible specially appropriated to this function; heart and blood-vessels are alike wanting, the great lacuna above described taking the place of both, since the fluid which it contains is evidently the representative of the blood, or, rather, it is the blood itself. Neither are there any special organs appropriated to respiration, which is here evidently carried on by the general surface of the body, as we have found it to be in many of the Entomostracous Crustaceans.

(1115.) The remarkable disposition of the alimentary canal so conspicuous in the Pycnogonidæ, and which exists, to a greater or less extent, among the inferior tribes of various classes of animals, has been named by M. de Quatrefages *"phlebenterism,"* from the circumstance that in the instance above given, and in many similarly-organized creatures, the intestinal ramifications supersede, to a greater or less extent, the functions of the circulatory, respiratory, and chyliferous systems of the higher animals.

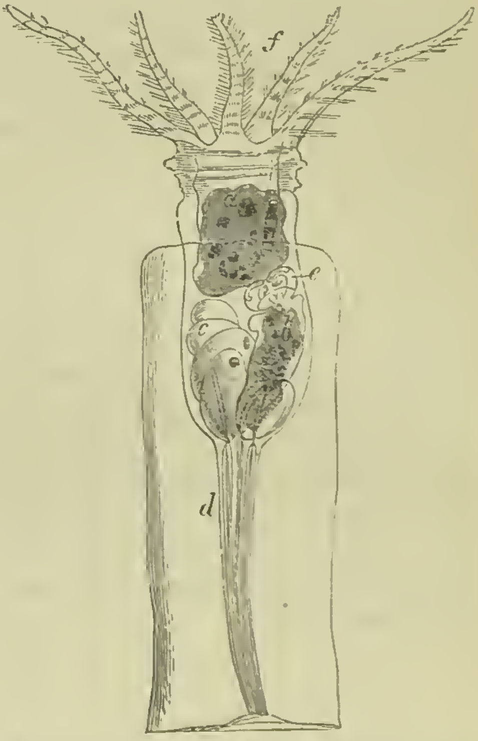
(1116.) The nervous system of the Pycnogonidæ consists of a thoracic chain of ganglia, from which are derived the nerves supplying the limbs, and of a supra-œsophageal mass, giving off the optic nerves to form the minute ocelli that constitute the visual organs of these extraordinary creatures.

CHAPTER XV.

ROTIFERA * (Ehrenberg).

(1117.) The class of animals that next presents itself for our consideration was, until very recently, confounded with the chaotic assemblage of minute creatures to which the name of *Infusorial Animalcules* was indiscriminately applied; but the information at present in our possession concerning their internal structure and general economy, while it exhibits in a striking manner the assiduity of modern observers and the perfection of our means of exploring microscopic subjects, enables us satisfactorily to define the limits of this interesting group of beings, and assign to them the elevated rank in the scale of zoological classification to which, from their superior organization, they are entitled.

Fig. 224.



Stephanoceros Eichhornii (after Ehrenberg): *a*, pharynx; *b*, stomachal cavity; *c*, ova contained in the ovary: *d*, retractile muscle; *e*, gizzard, containing the masticatory apparatus: *f*, rotatory organs, resembling those of a Bryozoon.

(1118.) The character whence the class obtains its name is derived from the peculiar organs placed upon the anterior part of the body, which are subservient to locomotion, and assist in the prehension of food. These consist of circlets of cilia variously disposed in the neighbourhood of the mouth, and having, when in action, the appearance of wheels spinning round with great rapidity, so as to produce strong currents in the surrounding water.

(1119.) The annexed engraving of the *Stephanoceros Eichhornii* † (fig. 224) exhibits an animal that would seem to be one of the connecting links by which the transition from the ARTICULATA to the MOLLUSCA is accomplished: the transparent cell, and ciliated tentacula around the mouth, would indicate this creature to be a BRYOZOON, to be described hereafter; but the tentacula are visibly stunted and thickened at their base, thus approximating in character to the cilia-bearing lobes of a Rotifer, while the internal organs (the pharynx, gizzard, and stomach) conform exactly to the type of structure common to the Rotifera.

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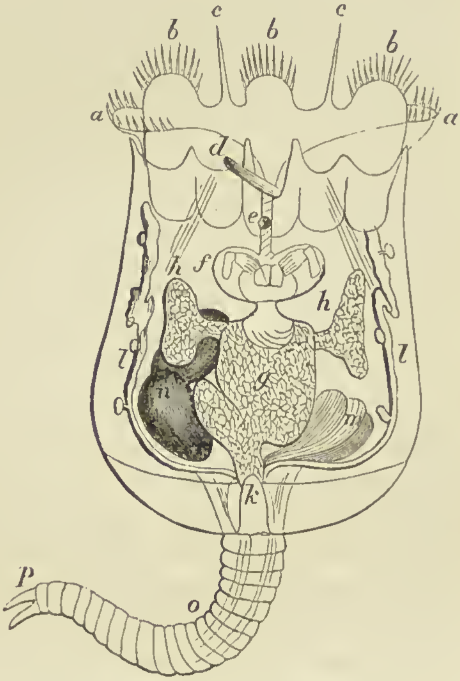
* *Rota*, a wheel; *fero*, I bear.

† Ehrenberg.

(1120.) The body of the Wheel-Animalcules is enclosed in a delicate transparent envelope of considerable consistency, often terminating at the upper extremity in wavy indentations and tooth-like processes, as in *Brachionus urceolaris* (fig. 225, *c c*). This harder integument is so constructed as to allow the animals to move at large in the element they inhabit. Continuous with the free margin of the shell is a delicate membrane connecting it with the bases of the cilia-bearing lobes around the mouth, so as to allow those organs, when not in use, to be retracted within the cell.

(1121.) To the posterior extremity of the body is generally appended a pair of forceps, composed of two moveable pieces (figs. 225 & 230), used as anchors, or instruments of prehension; and by means of these the little creatures fix themselves to the Confervæ or aquatic plants amongst which they are usually found. In *Brachionus urceolaris* the prehensile forceps (fig. 225, *p*) is attached to the extremity of a long flexible tail (*o*), wherein the muscular fibres destined for its motions are distinctly visible.

Fig. 225.



Brachionus urceolaris (after Ehrenberg): *a*, *b*, *c*, rotatory apparatus and marginal teeth of the shell; *d*, "calcar," or tubular prolongation of the shell, communicating with the visceral cavity; *e*, oculiform spot; *f*, gizzard with its enclosed masticatory apparatus; *g*, stomachal cavity; *h h*, cæcal appendages to the stomach; *k*, common outlet; *l*, lateral canals, to which the vibratory organs are attached *m*, contractile vesicle; *n*, ovaries; *o*, flexible tail, in which the muscular bands are distinguishable; *p*, terminal forceps.

(1122.) The cilia, whose action produces the appearance of wheels turning upon the anterior part of the body; are variously disposed; and from their arrangement Ehrenberg* has derived the characters whereon he bases the division of the class into orders. The peculiar movements excited by the vibration of these organs was long a puzzle to the earlier microscopic observers, who, imagining them to be really wheels turning round with great velocity, were utterly unable to conceive what could be the nature of the connexion between such appendages and the body of the animal. The apparent rotation has, however, been long proved to be an optical delusion, and to be produced by the progressive undulations of the cilia placed in the neighbourhood of the mouth.

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* Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin for 1833.

(1123.) With respect to the agents employed in producing the ciliary movement in the Rotifera, we are as much in ignorance as we are concerning the cause of the same phenomenon in the Polygastrica. Ehrenberg describes the cilia as arising from a series of lobes, as represented in *Notommata clavulata* (fig. 230, *a*); these he regards as being muscular, and capable of producing by their contractions the rapid vibrations of the fibrillæ attached to them. We confess, however, that such lobes, even were their existence constant, seem very clumsy instruments for effecting the purpose assigned to them; and it is not easy to conceive how the rapid and consecutive undulations, to which the appearance of rotation is due, can be produced by organs of this description.

(1124.) The observations of Dr. Arthur Farre* concerning the ciliary movements appear best calculated to throw light upon the nature of the action of these wonderful appendages, and to explain the cause of the apparent rotatory motion of the so-called wheels of the Rotifera. The very accurate observer alluded to remarks that, under high powers, the cilia have the appearance of moving in waves, in the production of each of which from a dozen to twenty cilia are concerned, the highest point of each wave being formed by a cilium extended to its full length, and the lowest point between every two waves by one folded down completely upon itself, the intervening space being completed by others in every degree of extension, so as to present something of the outline of a cone. As the persistence of each cilium in any one of these positions is of the shortest possible duration, and each takes up in regular succession the action of the adjoining one, that cilium which, by being completely folded up, formed the lowest point between any two waves, in its turn by its complete extension forms the highest point of a wave; and thus, while the cilia are alternately bending and unbending themselves, each in regular succession after the other, the *waves* only travel onward, whilst the cilia never change their position in this direction, having, in fact, no lateral motion.

(1125.) The whole of the ciliary movements are so evidently under the control of the animal as to leave not the slightest doubt in the mind of the observer upon this point. The whole fringe of cilia may be instantly set in motion and as instantaneously stopped, or their action regulated to every degree of rapidity. Sometimes one or two only of the waves are seen continuing their action, whilst the remainder are at rest; or isolated cilia may be observed slowly bending and unbending themselves, while the others are quiescent. It is by the constant succession of these movements that the eye is seduced to follow the waves which they seem to produce, and thus the apparent rotation of the wheels is easily understood.

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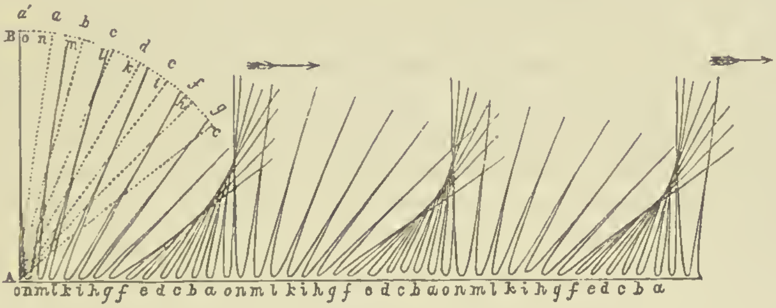
* Phil. Trans. for 1837.

(1126.) M. Dujardin's explanation of this phenomenon is based upon the fact, that if equal and parallel lines placed at equal distances from each other become bent at regular intervals, so as to overlap the neighbouring lines, they produce dark intersections somewhat resembling the teeth of a saw, instead of a uniform surface (fig. 226). In this manner the vibratile cilia, being arranged parallel to each other and separated by similar interspaces, would equally intercept the light, so that none would appear more conspicuous than others; but if, in consequence of a general movement propagated along such a row of cilia, some of them, by being momentarily bent down, are placed in juxtaposition with the neighbouring cilia, the light being more intercepted, a darker or more obscure line will be the consequence. It is easy, then, to conceive that, when all the cilia thus bend themselves in regular succession, numerous intersections of this kind will occur, apparently progressively advancing in the direction of the propagation of the movement; consequently, if each of these intersections whilst in motion preserves the same form, as being formed by the same number of equal lines the inclination of which is similar as respects each other, it will give to the eye the appearance of a solid body of a definite shape, such as the teeth of a saw, or of a wheel in uniform movement. In this way it is easy to understand how the circular rows of cilia in the Rotifera produce the appearance of a dentated wheel in motion*.

Fig. 226.


a′ a b c d e f g
B o n m l k i h
A
o n m l k i h g f e d c b a o n m l k i h g f e d c b a o n m l k i h g f e d c b a

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* To render intelligible the production of this wheel-like appearance by ciliary movement, we annex M. Dujardin's figure representing the position of a row of cilia at a given moment. In this, it is to be supposed that the straight cilia, which are parallel and equidistant from each other, are susceptible of successive oscillations, like the cilium A B, the first of the series,—each capable of describing by a uniform movement the angle B A *c*, of which the apex is at the point of attachment, by changing its position from the perpendicular, A B, till it attains the position A *c*, and

(1127.) Such being, as we conceive, the nature of the ciliary motion, we will proceed to examine the uses to which it is made subservient in the class of animals under consideration. A very slight examination of one of these creatures under the microscope will show that the cilia answer a double purpose: if the Rotifer fixes itself to some stationary object by means of the anal forceps, the ciliary action, by producing currents in the water all directed towards the oral orifice, ensures a copious supply of food, by hurrying to the mouth whatever minute aliment may be brought within the range of the vortex thus caused; or, on the other hand, if the animal disengages itself from the substance to which it held by its curious anchor, the wheels, acting upon the principle of the paddles of a steamboat, carry it rapidly along with an equable and gliding movement.

(1128.) The whole ciliary apparatus, when not in use, is retracted within the orifice of the shell, and lodged in a kind of sheath formed for it by the inversion of the tegumentary membrane. The muscular fasciculi by which this is effected are very conspicuous; they arise from the lining membrane of the shell, and run in distinct fasciculi in a longitudinal direction, to be inserted into the lobules whereon the cilia are arranged (fig. 230, *m m*).

(1129.) But, besides these retractor muscles, other fasciculi of muscular fibres are distinctly seen to run transversely, crossing the former at right angles: these are, most probably, the agents provided for the extrusion of the wheel-like apparatus; for, arising, as they do, from the inner membrane of the hard integument, they will, by their contraction, compress the fluid in which the viscera float, and, forcing it outward

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then returning with the same rapidity of motion to its first condition, A B, repeating continually similar movements in both directions. Now, as the other cilia of the series only commence this movement one after the other, each being in advance of the preceding one on the left hand by a fourteenth part of the space occupied by the entire wave, and the same distance from that which succeeds it on the right hand, at every fourteenth interval the cilia present themselves in the same state of flexure, and a row of cilia in motion presents, for the instant, the appearance represented in the figure, in which, at spaces of from fourteen to fifteen cilia, there is a shaded intersection, which advances with a uniform movement from left to right as each cilium successively assumes the position of that which follows it on the right-hand side.

Suppose, now, the duration of each oscillation divided into fourteen instants. a given cilium will occupy successively the positions A B, or A *o*. A *n*, A *m*, A *l*, A *k*, A *i*, A *h*, A *c*, in the space B A *c*, during the first half of the oscillation, the movement taking place from left to right. The other positions during the second half of the oscillation, the movement being from right to left, are, A *g*, A *f*, A *e*, A *d*, A *c*. A *b*, A *a*. —the position A *a'* being the same as A B, or A *o*, constituting the limit of the second half of that oscillation and the commencement of a new one.

In this manner the intersections, having the appearance of the teeth of a saw, will appear to advance with a uniform motion in the direction of the movement of oscillation, giving the appearance of a chain or row of pearls in motion in the case of a rectilinear row of cilia, or of a toothed wheel if the cilia are disposed in a circle.—*Vide* Dujardin, Hist. nat. des Infusoires.

towards the orifice of the shell, it will, of course, push before it the wheels, so as to evert the tegumentary membrane connecting them with the shell, by unrolling it like the finger of a glove, and thus causing the rotatory organs to protrude at the pleasure of the animal.

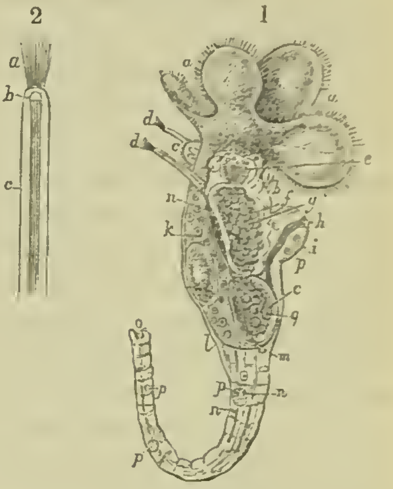
(1130.) We have already described the means whereby the Rotifera procure a supply of food, namely by exciting currents in the surrounding water ; the materials so obtained pass at once into a pharynx, the relative capacity of which varies considerably in different species ; from the pharyngeal receptacle it is conveyed into a singularly-constructed gizzard, to be bruised and broken down by an apparatus provided for that purpose ; thus prepared, it is allowed to enter a third cavity, wherein digestion is accomplished, which may be called the stomach, and this, after becoming gradually constricted in its diameter, terminates at the caudal extremity of the body.

(1131.) The usual arrangement of the digestive apparatus will be readily understood on reference to the annexed figures : thus, in *Stephanoceros Eichhornii* (fig. 224), the pharynx (*a*) is very capacious, receiving readily the materials brought into it by the ciliated arms ; the gizzard (*e*) is a small globular viscus, containing the instruments of mastication, hereafter to be noticed ; while the digestive cavity properly so called (*b*), which presents no perceptible division into stomach and intestine, extends from the gizzard to the anal aperture.

(1132.) In *Brachionus urceolaris* (fig. 225) the pharynx or œsophagus (*e*) is less capacious ; the gizzard (*f*) exhibits through its transparent coats the peculiar dental organs placed within it ; and the stomach (*g*) is seen partially folded upon itself by the retraction of the body. We observe, moreover, in this animal, appended to the commencement of the stomach, two large cæcal appendages (*h h*), which were scarcely perceptible in the last figure, and which, no doubt, are of a glandular nature, furnishing some fluid to be mixed up with the bruised aliment contained in the stomach, to assist in the digestive process. To these secreting cæca, Ehrenberg has chosen to give the name of pancreas ; but for what reason it is difficult to conjecture, since the first rudiments of a pancreas are only met with in animals far higher in the scale of animal existence ; every analogy, indeed, would lead us to denominate these cæca the first rudiments of a liver—by far the most important and universal of the glandular organs subservient to digestion, and in a variety of creatures we shall afterwards find it presenting equal simplicity of structure. In the *Notommata centrura* the cæca are merely two pouches opening into the top of the stomach, whereas in *Notommata clavulata* there are six of these appendages (fig. 230, *c c*) communicating with that enlarged portion of the digestive canal (*c*) which may be looked upon as the proper stomach.

(1133.) We must now revert to the consideration of the dental apparatus contained in the gizzard, represented *in situ* in fig. 225, *f*, and exhibited on a still larger scale in fig. 228. This curious masticating instrument consists of three distinct pieces, or teeth, which are made to work upon each other by the contractions of the gizzard, so as to tear in pieces or bruise all matters made to pass through the cavity containing them. The central piece (fig. 225, *f*) may be compared to an anvil, presenting on its upper surface two flattened facets; and upon these the other two teeth (that might, without much stretch of fancy, be compared to two hammers) act. Each of the superior teeth may be described as consisting of two portions united at an angle: the larger portion, or handle as it might be called, serves for the attachment of muscles; whilst the other part is free in the cavity of the gizzard, and works upon the facets of the anvil, the edge being apparently divided into teeth resembling those of a comb, and evidently adapted to bruise or tear substances submitted to their action. Such is the transparency of the whole animal, that the effect of these remarkable organs upon the animalcules used as food is distinctly visible under a good microscope; and if the Rotifer be compressed between two pieces of glass, so as to break down the soft textures of its body, the teeth may, from their hardness, be procured in a detached state for minute examination. The whole apparatus described above evidently resembles very closely the kind of stomach met with in the Crustacea, to which the Rotifera will be found gradually to approximate.

Fig. 227.



Melicerta ringens (after Prof. Williamson): *a a*, ciliated lobes, constituting the rotatory apparatus; *b*, hooks, called by Schäffer "the lips;" *c*, rotatory flap, or "pellet-cup" (Gosse); *d d*, tentacular organs; *e*, gizzard, containing the gastric teeth; *f*, upper stomachal cavity; *g*, inferior stomachal cavity; *h*, anal outlet; *i*, protuberance occasioned by the act of defecation; *k*, ovary; *l*, dilated oviduct; *m*, filamentary spermatic tube (?): *n n*, muscles of caudal appendage; *o*, prehensile organ; *p p*, corpuscles floating in the perivisceral fluid; *q q*, ova nearly ready for expulsion.

(1134.) In *Melicerta ringens* the alimentary canal commences with a small oval orifice situated near the sinuated disk formed by the rotatory organs. It opens into an œsophagus that conducts the food down to the gastric teeth (fig. 227, 1, *e*). These, according to Professor Williamson's very excellent memoir upon the subject*, are implanted in a large conglobate cellular mass, which completely invests them. Their appearance, when highly magnified, is accurately represented in fig. 228; they consist of two essential portions—a pair of strong crushing plates, which bruise the food, and various appendages affording leverage and facilitating the action of the muscles upon them. The crushers are two broad elongated plates (fig. 228, *a*), each being about $\frac{1}{800}$th of an inch long, and separated from each other at the mesial line, near which they become much thickened. From each of these plates there proceed laterally numerous parallel bars (fig. 228, *b b*), all of which are somewhat thickened at their inner extremities, where they are attached to the plates, whilst at their opposite ends they are united with the others of the same side by a curved connecting bar (fig. 228, *c c*), from the outer sides of which are given off various loops and processes. The three uppermost of these bars are the largest, the rest gradually diminishing in size as well as strength, till the inferior ones become almost invisible.

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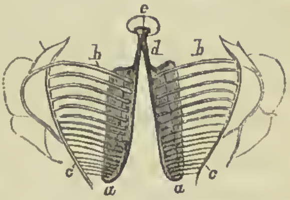
* Quarterly Journal of Microscopical Science, vol. i. p. 1.

Fig. 228.



Gastric dental apparatus of *Melicerta ringens*: *a a*, crushing plates; *b b*, *c c*, lateral framework; *d*, handle-like processes; *e*, central fixed point. (After Prof. Williamson.)

(1135.) From the upper extremities of the two crushers there project upwards and backwards two slender prolongations (fig. 228, *d*), which are united by a sort of double hinge near this apex, where they not only play upon each other, but also on a small central fixed point (fig. 228, *e*) lodged in a little conglobate cellular mass. Ehrenberg only describes three transverse bars on each side, which he regards as teeth; it is obvious that he has only noticed the three upper and larger pairs. It is equally evident that these transverse teeth, as he terms them, do not move upon the strong longitudinal plates, as he imagines, but are firmly united with them. Muscles are either attached to the divergent peripheral processes, or to the cellular mass in which these processes are imbedded, causing the entire apparatus to separate along the mesial line by means of the hinge-joint (fig. 228, *e*), the so-called teeth merely transmitting the motor force to the two longitudinal plates. These latter appendages are thus made to play upon each other with great power, and to act as efficient crushers, bruising the food before it passes into the stomach, as is the case with the gastric teeth of the Crustacea.

(1136.) From the above remarks it will be seen that, though in its construction the dental apparatus is more complex than is represented by Ehrenberg, in its mode of working it is less so. The conglobate organ in which this apparatus is imbedded is transparent, and composed of numerous large cells, each of which contains a beautiful nucleus with its nucleolus. The cells are only seen when the organ is ruptured between two plates of glass, when they readily separate from one another; but the nuclei, with their contained nucleoli, are distinctly visible in the living animal. Delicate muscular threads most probably penetrate this organ to reach the dental apparatus; but Professor Williamson has hitherto been unable to detect their presence satisfactorily.

(1137.) After passing the dental organs, the food enters an elongated stomach (fig. 227, 1, *f*) with very thick pulpy parietes. In young examples these walls are colourless and transparent, but in more matured specimens they exhibit a bright-olive hue. The whole cavity, as well as the œsophagus leading to it, is lined with cilia that are constantly playing. On rupturing this organ, it is seen to be composed of a thin pellucid external membrane, exhibiting no distinct structure, but within which is a thick layer of large, tinged epithelial cells. These are easily detached from the membrane, when each one is seen to be spherical, containing numerous yellow granules, and very often a nucleus with its nucleolus. The cilia are attached to one side of these cells, the great length of the former constituting the most marked feature of this arrangement; it often, indeed, equals the entire diameter of the cell. Some of the cells exhibit no cilia, others are only furnished with them on one side, while a few appear to be fringed with them throughout their entire circumference. Professor Williamson supposes that in the latter case the cells have projected considerably into the cavity of the stomach. The yellow granules are absent from those of young animals, showing clearly that it is these contained granules that give the colour to the parietes of the stomach.

(1138.) This stomach appears to be chiefly a receptacle for the food. From time to time, especially when the viscus is distended, portions of its contents pass down into a lower stomach (fig. 227, 1, *g*), which is separated from the upper one by a marked but varying constriction. The second stomach is also lined with cilia even larger than those of the upper viscus; but the parietes are very much thinner and more transparent, the cells being less easily traced. The diameter of the organ is nearly the same in each direction, so that it is almost spherical. The mass of food with which it is usually distended is constantly revolving, the motion being due to ciliary action. This process goes on for some minutes, after which the creature contracts its body and forces the entire contents out of this viscus into a long narrow cloaca that terminates externally by an anal outlet (fig. 227, 1, *h*). As it does this, it everts a considerable portion of the cloaca, thus almost bringing the cloacal outlet of the stomach to the exterior, and causing at the same time a large transparent protuberance (fig. 227, 1, *i*) to be developed on the corresponding side of its body. At other times the creature can draw in these appendages, so that scarcely any trace of a cloacal canal is visible.

(1139.) Notwithstanding the microscopic size of the Rotifera, and the consequent difficulty of detecting the more minute details of their structure, Ehrenberg thinks he has succeeded in discovering filamentary nerves, and nervous masses, distributed in different parts of their body,—an arrangement which not only would account for the complete association of their voluntary movements, but, from the presence of ganglia, would render these animals capable of possessing some of the local senses; indeed, Ehrenberg imagines he has discovered such to exist in the shape of red specks, to which he gives the name of eyes. The organ alluded to is a minute red spot, indicated in the figures (figs. 225 and 230); nevertheless no organization has been described of such a nature as to entitle us unhesitatingly to designate it an organ of vision, even if it should, as he intimates, invariably be in connexion with a nervous mass, which, from examining his drawing of the arrangement of the nerves, we should have little expected to be the case.

(1140.) The nervous system of *Notommata clavulata*, as described by this indefatigable observer, is represented in fig. 230. It would seem to consist of several minute nodules (fig. 230, *i i*), exhibiting a somewhat symmetrical arrangement, and disposed apparently in pairs; some of these nodules, which are about ten in number, communicate with each other by delicate filaments, whilst others seem to be quite insulated from the rest.

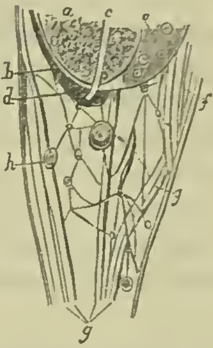
(1141.) Every one who is acquainted with the difficulty of conducting microscopical observations, especially with the high powers needful in detecting structures so minute as the nerves of the Rotifera, will be exceedingly cautious in admitting the complete establishment of facts involving important physiological principles; and we cannot help thinking that Ehrenberg has been misled by some appearances which it is impossible for the most correct observer always to guard against, in assigning to the Rotifera an arrangement of the nervous system so totally different from what is met with in any other class of animals as that represented in his figure, from which our engraving has been accurately copied.

(1142.) All our ideas of the physiology of the nerves would lead us to suspect some error. The uses of ganglia, as far as we know at present, are either to associate nerves derived from different sources, or to serve as centres for perception, or else they are for the concentration of nervous energy. The position of the ganglia depicted in the figure as being in relation with the nervous threads would scarcely seem to be consistent with either of the above offices; and therefore we cannot but regard the observations that have been hitherto recorded concerning the nervous system of the Rotifera as far from being complete.

(1143.) Professor Williamson observes that these small organs, which are so common amongst the Rotifera, and which Ehrenberg regards as nervous ganglia, are abundant in tho *Melicerta*, but they afford no countenance to the hypothesis of the great Prussian Professor. They appear to be nothing more than small cells or vesicles, formed of granular viscid protoplasm, very similar to those into which the yelk of the egg becomes divided. Sometimes they float freely in the fluid which distends the integument and bathes the viscera; at others, thin ductile threads pass from one vesicle to another, as represented in fig. 229, *h*, where these objects are delineated as they appeared in one individual, in the clear space immediately below the viscera. They differ as widely as possible in their size, number, and proportion. So far from being nervous vesicles, they appear rather to be cells modified into a rudimentary form of areolar tissue. That they are hollow vesicles or cells, very viscous, readily cohering, and, owing to this coherence, easily drawn out by the movements of the various organs to which they are attached, are facts capable of easy demonstration.

(1144.) Leydig conceives the nervous system of *Lacinularia* to consist of, first, a ganglion situated behind the pharynx, composed of four bipolar cells with their processes; secondly, of a ganglion at the beginning of the caudal prolongation, composed of four larger ganglionic cells and their processes. The last-mentioned cells are described by Professor Huxley as vacuolar thickenings—finding no difference whatever between them and the thickenings in the disk, which Leydig himself allows to be mere thickenings.

Fig. 229.



Lower half of the body of *Melicerta ringens*, highly magnified: *a*, lower stomach; *b*, *c*, lower portion of ovary and oviduct; *d*, intestine; *e*, filamentary spermatic tube (?); *f*, *g g*, retractor muscles; *h*, corpuscles swimming in the peri-intestinal fluid, regarded by Ehrenberg as nervous ganglia.

(1145.) Professor Huxley's own view upon the subject is as follows*:—On the oral side of the neck of the animal, or, rather, upon the under surface of the trochal disk, just where it joins the neck, and therefore behind and below the mouth, there is a small hemispherical cavity, which seems to have a thickened wall and is richly ciliated within. Below this sac, but in contact with its upper edge, is a bilobed homogeneous mass, which Professor Huxley believes to be the true nervous centre.

(1146.) On the nuchal region of many species of Rotifers are two remarkable organs (fig. 227, 1, *d d*), which, from their structure, appear to perform the office of tentacula, although various uses have been assigned to them by different observers. Ehrenberg supposed them to be connected with the respiratory functions, while Dujardin compares them, with much greater probability, to the antennæ and palpi of the Entomostracous Crustaceans. In *Melicerta ringens*†, these organs, when fully protruded, are seen to be terminated by a brush of fine divergent setæ (fig. 227, 2, *a*), implanted on the convex side of a small deltoid body (*b*); from the flat side of this latter appendage there proceeds along the interior of the tube, towards the body of the animal, a delicate muscular band (*c*), which by its contractions draws the deltoid body backwards, thus inverting the extremity of the tube, and forming a double sheath protecting the setæ. The whole apparatus, observes Professor Williamson, is very similar to that seen in the tentacles of the Snail, and appears to constitute rather a tactile than a respiratory organ. This is rendered the more probable by the fact that, when the animal first emerges from its tessellated case, the extremities of these two tentacles are the first parts to make their appearance, the two curved hooks, named by Schäffer the lips (fig. 227, 1, *b*), being the next. The setæ are usually half drawn into the inverted tentacle, but they project sufficiently forward to constitute delicate organs of touch, supposing the deltoid body, into which they are implanted, to be endowed with sensibility. The animal cautiously protrudes these tentacles before it ventures to unfold its rotatory organs; but it does not direct them from side to side, as an insect does its antennæ.

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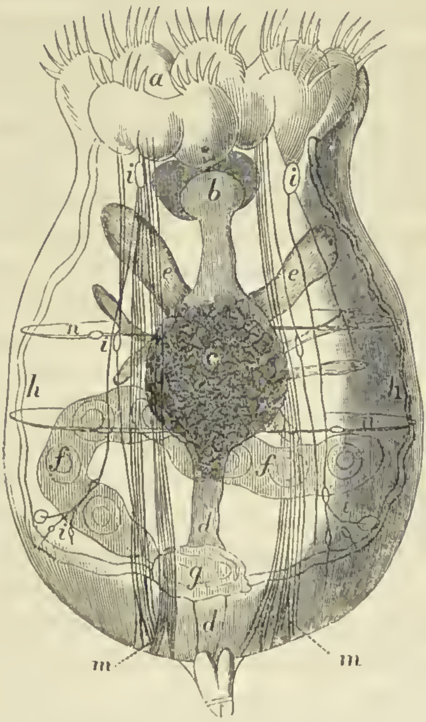
* Quarterly Journal of Microscopical Science, no. 1. p. 9. † Williamson, *loc. cit.*

(1147.) In addition to the elaborate organization described above, the Prussian naturalist conceived that he had discovered a vascular apparatus, consisting of transverse vessels (fig. 230, *n n*), in which he supposed a circulation of the nutritive fluids occurred. But the vascular character of the transverse striæ visible in this position is more than doubtful, as there seems every reason to suppose that the appearance depicted in the figure is due to the existence of the transverse muscular bands whereby the extrusion of the rotatory apparatus is effected, analogous to those occupying a similar situation in the Bryozoa.

Fig. 230.



Notommata clavulata (after Ehrenberg): *a*, rotatory organs; *b*, gizzard; *c*, stomach; *d d*, intestine; *e*, cæcal appendages to stomach: *f*, ovary; *g*, contractile vesicle; *h h*, lateral tubes, to which are appended the vibratory organs; *n n*, transverse bands, supposed by Ehrenberg to belong to a vascular system.

1148.) The mode in which respiration is effected, in the class of animals under consideration, has been a subject of much dispute. Some have supposed the contact of water, applied to the general surface of the body, sufficient for the aëration of the nutritious juices, especially as its constant renewal would be ensured by the ciliary movements. Bory St. Vincent*, on the contrary, regarded the rotatory cilia as real gills, resembling those of fishes; and, mistaking the movements of the gizzard for the contractions of a heart, conceived these animalcules to be even superior to insects in the organization of their vascular system. Ehrenberg, however, thinks that he has discovered an internal respiratory apparatus of a most extraordinary description. In *Notommata centrura* he remarked seven vibrating points on one side, and six on the other, attached to two long and undulating viscera, which he elsewhere describes as being the testes of the animal (fig. 225, *l*); the above-mentioned points were never at rest, and appeared to be placed in determinate positions opposite to each other. Accurate observations, he says, have shown each to be a peculiar little organ, provided with a tail resembling that of a note in music, and to be thrown into vibration by three little vesicles, or folds of their inflated extremity; these organs floated freely in the abdominal cavity by their enlarged portion, while by their tail they were attached to the long tubular organ above referred to.

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* Dict. des Sci. Nat., art. "ROTIFERA."

(1149.) Ehrenberg's first idea on seeing these organs was that they formed a vascular system, executing movements of pulsation; but he now considers them as internal branchiæ, or organs of respiration, to which the external water is freely admitted in the following manner:—

(1150.) In many species of the Rotifera, we find, projecting from the neck of the animal, a horny tubular organ, called by Ehrenberg the *calcar* or spur (fig. 225, *d*): this he at first considered to be the male organ of sexual excitement; but he now regards it as a siphon, or a tube of respiration, through which the circumambient water passes freely into the cavity of the body. He thinks, moreover, that the periodical transparency, and the alternate distention and collapse of the animal. seen to occur regularly in almost all the Rotifera, are produced by the introduction of water into the visceral cavity and its subsequent expulsion therefrom, upon which action the fluctuations observed in the interior of the body would therefore depend. The supposition that water is injected in this manner into the body seems to be favoured by other appearances: for when the internal cavity is thus filled, all the viscera appear isolated, so that the boundaries of each can be distinctly seen; but when the water is discharged, they approximate each other, their limits become confounded, and the external membrane of the body assumes a crumpled appearance.

(1151.) Upon reviewing the above account of the mode of respiration in the Rotifera, we must say that we consider that the office assigned to the little organs called branchiæ is extremely problematical, especially as we have but the most vague intimations concerning the existence of a circulating system at all, much less of such a double circulation carried on in arteries and veins as the presence of such organs would infer. "I presume," says Ehrenberg, "that the branchiæ possess a vascular system; for when the local contractions occur in the body of the animal, we see distinctly a certain number of filaments (vessels?) loose and delicate." The opinions of the Professor himself concerning the nature of the organs which he describes being so indefinite, we must pause before adopting the physiological views to which their admission would lead—more especially as, from the very fact of the whole visceral cavity being perpetually filled with aërated fluid, the existence of any localized organs of respiration could hardly be esteemed necessary.

(1152.) The two lateral bands above mentioned (fig. 225, *l*), with which are connected the "trembling gill-like organs" of Ehrenberg, are now considered as constituting a peculiar apparatus, distinguished as the "*water-vascular system,*" of which, as they exist in *Lacinularia socialis,* the following description is given by Professor Huxley*. In this species there is no contractile sac as in other genera; but two very delicate vessels, about $\frac{1}{4000}$th of an inch in diameter, clear and colourless, arise by a common origin upon the dorsal side of the intestine. The vessels separate, and one runs up on each side of the body in the direction of the mouth. Arrived at the level of the pharyngeal bulb, each vessel divides into three branches: one passes over the pharynx and in front of the pharyngeal bulb, and unites with its fellow of the opposite side; while the other two pass, one inwards and the other outwards, in the space between the two layers of the trochal disk, and there terminate as cæca. Besides these, there seemed sometimes to be another branch just below the pancreatic sacs.

(1153.) A vibratile body is contained in each of the cæcal branches, and there is likewise one on each side in the transverse connecting branch. Two more are contained in each lateral main trunk, one opposite the pancreatic sacs, and one lower down, making in all five on each side. Each of these vibrating bodies is a long cilium ($\frac{1}{1000}$th of an inch), attached by one extremity to the side of the vessel, and by the other vibrating with a quick undulatory motion in its cavity, giving rise, as Siebold remarks, to an appearance singularly like that of a flickering flame.

(1154.) The last subject that we have to consider relative to the internal economy of the Rotifera is the conformation of their generative apparatus, which here assumes a considerable perfection of development. The reproductive system is composed apparently of two distinct parts; the one subservient to the formation of the ova, the other destined either to furnish some secretion essential to the completion of the egg, or, as has been surmised, secreting a fertilizing fluid by which the impregnation of the ova is effected prior to their escape from the body.

(1155.) In *Melicerta ringens,* as we learn from Professor Williamson's admirable memoir, the ovary is a hollow sac, consisting of a very thin pellucid membrane, filled with a viscid granular protoplasm of a light-grey colour, in which may be perceived some twenty or thirty nuclei, each containing a nucleolus in its interior; these seem to be successively selected for development after the following manner:—One of the nuclei situated near the surface of the ovary attracts around it a small portion of the granular protoplasm, which becomes detached from the remaining contents of the ovary. The portion thus specially isolated gradually enlarges, assuming at the same time a darker hue, and the nucleus slightly enlarges, while its central nucleolus appears to become absorbed. When the ovum, thus separated from the ovarian protoplasm, has attained its full size, it becomes invested by a thin shell, which is apparently a secretion from its own surface. The ovum being thus ready for expulsion (fig. 227, 1, *q*), is slowly forced down to the lower part of the ovary, and, sweeping round the inferior border of the lower stomach, passes through the dilated oviduct (fig. 227, 1, *l*) and enters the cloaca, whence, by a sudden contraction, it is expelled.

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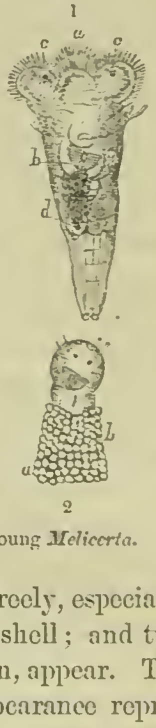
* Quarterly Journal of Microscopical Science, no. 1. p. 6.

(1156.) At this point of development the yelk consists of a single segment; but very soon the central nucleus becomes drawn out and divides into two, this division being followed by a corresponding segmentation of the yelk. The same process is repeated over and over again, until at length the yelk becomes converted into a mass of minute cells. The first trace of further organization which presents itself appears in the form of a few freely-moving cilia; these are developed at two points, one at *c a*, fig. 231, 1, which corresponds with the future head, and the other near the centre of the ovum (*b*), which is destined to become the cavity of the stomach; shortly after this appearance of cilia, traces of the dental apparatus become recognizable,—this, again, being soon succeeded by the union of the entire mass of yelk-cells, and the formation from them of the various organs of the animal. The cilia now play very freely, especially at the head (*a*); the creature twists itself about in its shell; and two red spots (*c c*), regarded by Ehrenberg as organs of vision, appear. The young animal now bursts its shell, and presents the appearance represented in fig. 231,—its whole organization, though obscurely seen, being that of the perfect animal, and not of a larval state.

Fig. 231.



Young *Melicerta.*

(1157.) The young Melicerta, when first hatched, is free, and swims about actively in the water for a short period, when, attaching itself by its caudal extremity to some foreign object, it proceeds to manufacture for itself a tube for its future residence by means of a most remarkable apparatus appointed for the purpose. This is the appendage called by Professor Williamson the fifth rotatory flap (fig. 227, 1, *c*), and named by Mr. Gosse* the "*chin*" or "*pellet-cup*," in which the minute masses whereof the tube is formed are prepared. Into this cup-like organ foreign particles are continually brought, at the will of the animal, by ciliary action, and collected into little pellets, which are deposited as quickly as they are completed in successive rows around the foot, until a tube is formed of sufficient size for the lodgment of the little Rotifer (fig. 231, 2, *a*, *b*).

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* Quarterly Journal of Microscopical Science.

(1158.) In the remarkable genus *Asplanchnia,* it has been ascertained by Mr. Dalrymple* that these animals are bisexual, and, moreover, that the male individual is one of the strangest organisms as yet discovered. In the female the sexual apparatus is very completely developed, consisting of an ovary, an ovisac, vaginal canal, and vulva, the whole being so transparent that the development of the embryo throughout all its stages is readily observable, and its progress traced from the time of the formation of the egg to its birth. The eggs are of three kinds: the first is of ordinary structure, wherein the formation of the female embryo is easily witnessed while contained in the body of the parent; but towards the latter end of the season, ova are furnished of a totally different character, which are apparently destined to remain through the winter undeveloped until the following year. In a third description of ovum an embryo may be observed to become developed gradually from a germinal vesicle until it begins to assume a definite shape and independent movement, when we are at once struck with the remarkable peculiarities observable in its form, size, and organization; and this is the male, which will require special description.

(1159.) This male is about $\frac{2}{5}$ths of the size of the female, generally resembling it in shape, but more flattened at the lower part, or fundus, and more prolonged at the side, corresponding to the vaginal opening in the female, which in the male presents a similar valvular opening, though comparatively smaller in extent. Within this valve is observed a short canal, leading to a large spherical bag, which may be distinctly seen to be filled with molecular bodies in a constant tremulous movement. From this sac, which Mr. Dalrymple denominates the "sperm-bag," a short but thick rounded body projects into the canal before mentioned as leading to the lateral opening; and around the extremity of this projecting process, and even within it to a short distance, is a visible ciliary motion, indicating a canal; on the neck of the sperm-bag is a fasciculus of delicate muscular fibres, which are inserted along the commencement of this evident *penis*, and over the latter organ the membranous sheath is reflected. Muscular bands, arising from the tegumentary parietes of the animal, in the vicinity of the valvular opening, go to be inserted into the root of the penis, and may be frequently observed drawing it up to the opening, and even extending it beyond the body of the animal. Muscles also for the purpose of opening the valve, very similar to those employed for the same purpose in the female, and the bands which bring the penis forward, clearly show it to be an extrusory organ, and to form a complete male apparatus. The sperm-bag evidently contains active spermatozoa.

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* *Vide* Phil. Trans. for 1849, pls. 33 & 34.

(1160.) Although Mr. Dalrymple never had an opportunity of observing any action beyond the extrusion of the penis, Mr. Brightwell, of Norwich*, has observed in seven different instances the direct copulation of the two sexes—clearly demonstrating this important fact, and thus establishing the diœcious character of this remarkable family.

(1161.) But there is another circumstance connected with these Rotifers, almost without parallel in the animal creation. The male, as has been said, possesses the same general figure as the female; it has also the contractile cloacal cavity, named by Mr. Dalrymple "the respiratory sac," as well as the "water-system," furnished with the vibratory or ciliated tags. It has also the ordinary rotiferous apparatus at the head, through the agency of which its various movements of locomotion are performed; the red "eye-spot" likewise is distinct. *It has, however, no mandibles, no pharynx, œsophagus, pancreatic glands, or stomach*; there appear to be no organs of deglutition, digestion, or assimilation; only, at the lower part of the animal, on the other side of and opposite to the valvular opening, are three small oval bodies massed together, having no communication by tube or otherwise, but fixed in their places by short ligaments that may be rudiments of a stomach.

(1162.) The difference of sex in these two forms, proceeding from the eggs of the same individual, is plainly evidenced by the fact, not only of the difference of structure, and the presence of active spermatozoa in the male, but by the observed fact of the intromission of the male organ into the vaginal canal of the female. That the male animal is produced by the female, and developed within the ovisac in the same manner as the female embryo, is also proved by many observations. The absence of all organs for the sustentation of life by food leads to the belief that it is created for a single purpose, and that its term of existence is very short. In this respect it somewhat resembles the drone, or male bee, whose utility seems to be confined to the impregnation of the perfect female or queen.

(1163.) That a single impregnation is sufficient for the production of many young is proved by the female continuing to breed in water in which no male can be discovered; but young females so produced will not go on to develope others unless a male be born amongst them.

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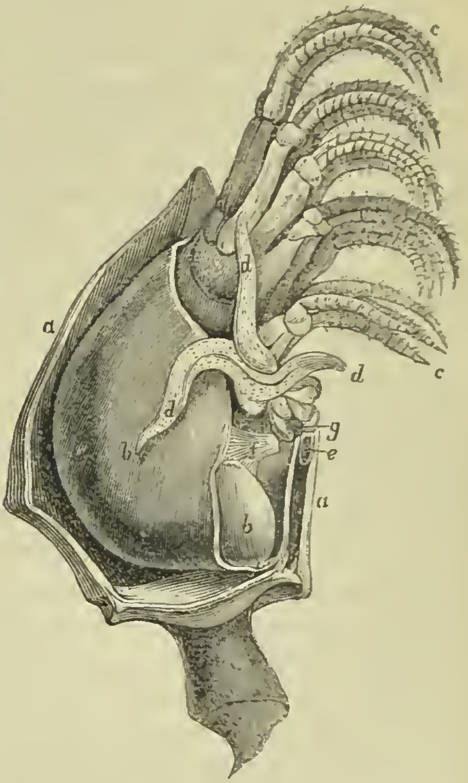
* *Vide* Ann. of Nat. Hist. for Sept. 1848.

CHAPTER XVI.

CIRRHOPODA.

(1164.) The Cirrhopoda present a strange combination of articulated limbs united with many of the external characters of a Mollusk, as will be at once evident from the examination of any species of Barnacle, whether sessile or pedunculated. We select a common form, *Pentelasmis vitrea*, as an example of the kind last mentioned. The animal in question is enclosed in a shell resembling in some respects that of the common Mussel, but composed of five distinct pieces united together by a dense intervening membrane: of these, four pieces are lateral, and disposed in pairs; while a fifth, which is single, is interposed between the posterior edges of the two valves, so as to unite them along the whole length of the back. Along the anterior margin the valves are only partially connected by membrane; so that a long fissure is left, through which the articulated extremities may be protruded. In place of the hinge that joins the two shells of the Mussel, we find the tough coriaceous membrane that unites the different shelly pieces of the integument of *Pentelasmis* prolonged into a cylindrical pedicle (fig. 235, *l*), which is in some species many inches in length, and, being attached by its extremity to any submarine body, fixes the animal permanently to the same locality. The external layer of this pedicle is coriaceous, or almost corneous, in its appearance, being evidently an epidermic structure; but internally the tube is lined with a layer of strong muscular fibres arranged longitudinally (fig. 235, *m*, *n*), which by their contraction are no doubt able to bend the flexible stem in any given direction, and thus confer upon the animal a limited power of changing its position when necessary. On removing one-half of the shelly covering (as in fig. 232, *a a*), we expose the body of the Cirrhopod, and discern the following particulars. The lower portion of the body, which encloses the principal viscera (*b b*), is soft and much dilated, especially towards the dorsal region; this part of the animal is covered with a delicate membrane, beneath which is a layer of whitish granular substance. The mouth (*g*) is seen upon the ventral aspect, situated immediately at the inferior extremity of that longitudinal fissure in the mantle through which the arms are protruded: the oral aperture appears to be raised upon a prominent tubercle, and, when attentively examined, is found to be provided with a rudimentary apparatus of jaws, presenting a distinct lip, furnished with minute palpi, and three pairs of mandibles, of which the two external are horny and serrated, while the third remains permanently soft and membranous. Immediately behind the mouth, we find on each side certain pyramidal fleshy appendages (*d d d*), resembling, as Hunter expressed it, a minute Star-fish, which no doubt constitute the branchial or respiratory organs. Commencing above the mouth, we further notice on each side six pairs of articulated and flexible arms or cirri (fig. 232, *c c*), each being composed of a series of semi-corneous pieces, and exhibiting at each joint long and stiff hairs. Every pair of cirri arises from a single prominent stem; and those most distant from the mouth being the longest and most extensile, the whole apparatus, consisting of twenty-four cirri, forms, when protruded from the body, a kind of net of exquisite contrivance, in which passing particles of nourishment are easily entangled, and thus conveyed to the mouth. Lastly, on separating the cirriferous pedicles, we find, terminating the body, and forming, as it were, a kind of tail, a long, soft, and flexible organ (fig. 235, *k*), the extremity of which is perforated by a minute aperture; but the real nature of this instrument we shall examine by and by.

Fig. 232.



Pentelasmis vitrea: *a a*, the shelly valves; *b b*, body contained within the shells: *c c*, the cirri: *d d d*, presumed branchial apparatus; *e, f*, muscular expansions; *g*, the mouth. (After Hunter.)

(1165.) On reviewing this general description of the external construction of *Pentelasmis*, the reader cannot but be struck with the singular combination of characters which it exhibits. Judging from its shell alone, its right to be considered a Mollusk would seem to be at once demonstrable; for, in fact, most conchologists agree in claiming these animals as belonging to their own department; and yet if, after removing the shell, we compare the animal with a Crustacean, its alliance with that class is equally evident. Suppose the body (fig. 232, *b b*) to represent the thoracic portion of a Crustacean slightly bent upon itself, and enclosed in an extensively developed thorax*; the valves of the shell would represent this thorax, which would be divided into five pieces; the first pair of cirri arising from the body would then represent the true feet of a Crustacean; the branchiæ would occupy the same position in both; the rest of the body of the Barnacle, namely that which supports the five other pairs of feet, would represent the tail of the Crustacean, and the ciliated, natatory feet, generally connected with that part of the external skeleton. Even the mouth, as the author referred to might have added, with its triple series of jaws, is more nearly allied in structure to that of the Crustaceans than to anything we shall meet with in the structure of the oral organs of true Mollusca.

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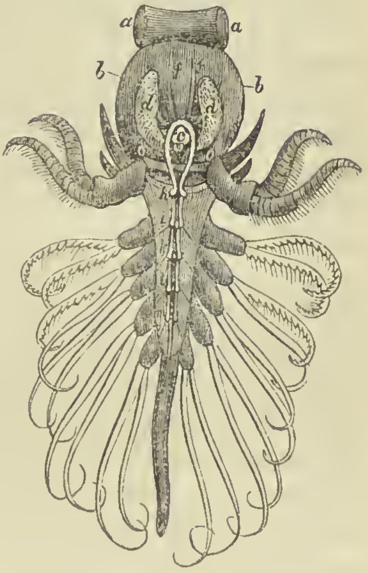
* Cuvier, Mémoire sur les Animaux des Anatifes et des Balanes, et sur leur Anatomie, p. 6.

(1166.) But the affinity which unites the Cirrhopoda to the Homogangliata is not merely exemplified in the analogies that can be pointed out between the external configuration of *Pentelasmis* and some Crustacean forms; the nervous system even, as we might be led to anticipate from the symmetrical arrangement of the articulated cirri, still exhibits the Homogangliate condition, and, besides the supra-œsophageal masses, forms a longitudinal chain of double ganglia arranged along the ventral surface of the body, from which the nerves supplying the cirriferous arms take their origins. Four small tubercles (fig. 233)*, placed transversely above the œsophagus, represent the brain, and give origin to four principal nerves (*f f f f*), which are distributed to the muscles and viscera; for in such a situation, organs of sense would evidently be useless. Two lateral cords, derived from the above, surround the œsophagus, from each of which a nerve (*o o*) is given off. Below the œsophagus the nervous collar terminates in a pair of ganglia (*h*), that give origin to the nerves supplied to the first pair of arms; and then succeeds a parallel series of double ganglia (*i, k, l, m*), exactly resembling those of articulated animals, from which emanate nerves that are destined to the cirri and surrounding parts.

Fig. 233.



Pentelasmis vitrea, exhibiting the nervous system: *a a*, the pedicle; *b b*, the body; *c*, the mouth; *d d*, glandular masses; *f f*, visceral nerves; *o o*, nervous collar surrounding the œsophagus; *h*, *i*, *k*, *l*, *m*, series of double ganglia supplying the articulated cirri. (After Cuvier.)

(1167.) The muscular system of *Pentelasmis* is partly appropriated to the movements of the shell and partly to the general motions of the body. The shell is closed by a single transverse fasciculus of muscular fibres, whereof a section is seen at *e*, fig. 232, placed immediately beneath that fissure in the mantle through which the arms are protruded; it passes directly across from one valve to the other, and approximates them by its contraction.

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* Cuvier, *loc. cit.*

(1168.) A large muscle, whose origin is seen in fig. 232, *f*, arises from the interior of the mantle, and, as its fibres diverge, spreads over the entire mass of the viscera; this will evidently draw the body forward and cause the protrusion of the tentacula; while various muscular slips derived from it scarcely need further description, being destined to move the numerous arms, with their jointed cirri and the fleshy tubular prolongation (fig. 235, *k*) already noticed.

(1169.) The food devoured by the Cirrhopoda would seem to consist of various minute animals, such as small Mollusks and microscopic Crustacea, caught in the water around them by a mechanism at once simple and elegant. Any one who watches the movements of a living Cirrhopod will perceive that its arms, with their appended cirri, are in perpetual movement, being alternately thrown out and retracted with great rapidity, and that, when fully expanded, the plumose and flexible stems form an exquisitely beautiful apparatus, admirably adapted to entangle any nutritious molecules, or minute living creatures, that may happen to be present in the circumscribed space over which this singular casting-net is thrown, and drag them down into the vicinity of the mouth, where, being seized by the jaws, they are crushed and prepared for digestion. No sense but that of touch is required for the success of this singular mode of fishing; and the delicacy with which the tentacula perceive the slightest contact of a foreign body shows that they are eminently sensible to tactile impressions. As regards the digestive organs, we have already described the prominent mouth (fig. 235, *b*), with its horny palpiferous lip and three pairs of lateral jaws. The œsophagus (*c*) is short, and firm in its texture; it receives the excretory ducts of two salivary glands of considerable size (fig. 233, *d d*), and soon terminates in a capacious stomachal receptacle, the walls of which are deeply sacculated and surrounded by a mass of glandular cæca (fig. 235, *d*) that represent the liver, and pour their secretion through numerous wide apertures into the cavity of the stomach itself. The intestine (*e*, *f*) is a simple tube, and runs along the dorsal aspect of the animal, wide at its commencement, but gradually tapering towards its anal extremity; it terminates at the root of the tubular prolongation (*k*) by a narrow orifice, into which a small bristle (*g*) has been inserted.

(1170.) Little is satisfactorily known relative to the arrangement of the blood-vessels and the course of the circulation in these animals. Poli imagined that he had discovered a contractile dorsal vessel, intimating that he had perceived its pulsations in the vicinity of the anal extremity of the body; and although his observations upon this subject have not been confirmed by subsequent investigations, analogy would lead us to anticipate the existence of the heart in the position indicated by the indefatigable Neapolitan zootomist. The lateral appendages (fig. 232, *d d d*) are most probably proper branchial organs, but, perhaps, not exclusively the instruments of respiration, since the numerous cirri no doubt cooperate in exposing the blood to the action of the surrounding medium, a function to which they are well adapted by their structure and incessant movements; especially as each cirrus is seen under the microscope to be traversed throughout its whole length by two large vascular trunks, one apparently arterial, and the other of a venous character.

(1171.) Judging from the peculiar conditions under which the Cirrhopods exist, it would only be natural to suppose that to creatures so circumstanced, the possession of the organs of the higher senses would be a useless incumbrance, seeing that they are apparently quite incapable of holding communication with the external world; nevertheless, from the recent discoveries of Professor Leidy* and of Mr. Darwin†, they are found to be by no means destitute in this respect. In *Lepas fascicularis*, Mr. Darwin detected two nervous filaments, derived immediately from the front of the two supra-œsophageal ganglia, which were found to terminate in two small, perfectly distinct, oval masses, which are not united by any transverse commissure. From the opposite ends of these two ganglia, smaller nerves are derived, which, bending inwards at right angles, communicate with the ocular apparatus, which, although apparently consisting of a single mass, is, in reality, composed of two eyes united together; or, in other words, although in outline the eye appears single, two lenses can be distinctly seen at the end, as well as two pigment-capsules, which are deep and cup-shaped, and of a dark reddish-purple hue. This double eye, in all the genera examined, is seated deep within the body: it is attached by fibrous tissue to the radiating muscles of the lowest part of the œsophagus, and lies actually on the upper part of the stomach; consequently a ray of light to reach the eye has to pass through the exterior membrane and underlying corium and to penetrate deeply into the body. In living sessile Cirripeds, Mr. Darwin observes, vision seems to be confined to the perception of the shadow of an object passing between them and the light; they instantly perceive a hand passed quickly at the distance of several feet between a candle and the vessel in which they may be placed.

(1172.) In the outer maxillæ, at their bases, where they are united together, but above the basal fold separating the mouth from the body, there are, in all the Lepadidæ, a pair of orifices, sometimes seated on a slight prominence, or else on the summit of flattened tubes projecting upwards and towards each other. Each of these orifices leads into a deep sac lined by pulpy corium, and closed at the bottom, over which a nerve of considerable size is distributed. That this closed sac is an organ of senso, of some kind or other, there can be little doubt; and, judging from its position, Mr. Darwin is induced to consider that the two constitute an olfactory apparatus.

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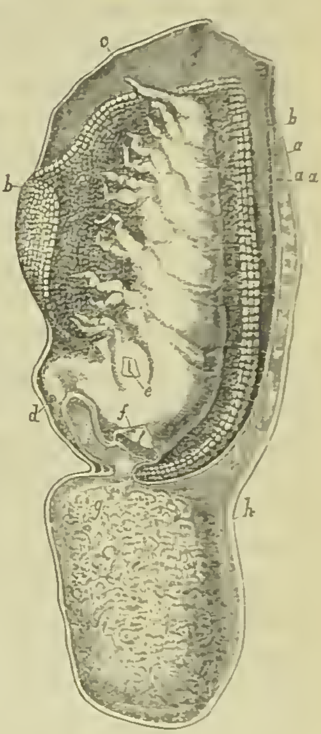
* Proceedings of the Academy of Natural Sciences of Philadelphia, Jan. 1848.

† Monograph on the Subclass Cirripedia, by Charles Darwin, F.R.S., 1841.

(1173.) At a little distance beneath tho basal articulation of the first cirrus, on each side, there may be seen a slight swelling, and on the under side of this a transverse slit-like orifice (fig. 234, *e*), one-twentieth of an inch in length, in *Conchoderma*, but often only half that size: this is regarded by Mr. Darwin as the organ of hearing. The external orifice leads into a deep and rather wide meatus, which, enlarging upwards, is lined by a thick pulpy corium, and is closed at the upper end; from its summit is suspended a flattened sac, variously shaped in different genera. In all cases the sac is empty, or contains only a littlo pulpy matter; it consists of brownish, thick, and remarkably elastic tissue, formed apparently of transverse little pillars, becoming fibrous on the outside, and with their inner ends appearing like hyaline points. The mouth of the acoustic sac is closed by a tender diaphragm, through which Mr. Darwin thinks he saw a moderate-sized nerve enter; and as the first pair of cirri seem, to a certain extent, to perform the office of antennæ, therefore the position of an acoustic organ at their bases is analogous to what exists in Crustacea; but there are not here any otoliths, or the siliceous particles and hairs, as described by Dr. Farre in that class (§ 1050). Nevertheless the sac is so highly elastic, and its suspension in a meatus freely open to the water seems so well adapted for an acoustic organ, that Mr. Darwin considers such to be its function.

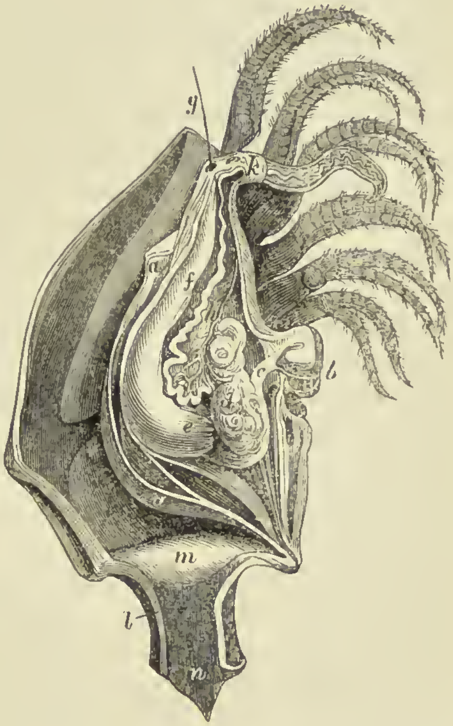
Fig. 234.



Structure of *Conchoderma*: *a*, external layer of integument: *a a*, internal layer; *b b*, ova, forming a layer around the body; *c*, ovipositor: *d*, mouth; *e*, presumed organ of hearing; *f*, aperture communicating with the interior of the pedicle; *g*, *h*, pedicle. (After Darwin.)

(1174.) With respect to the organization of the reproductive system in these creatures, the most discordant opinions are expressed by different writers, no two authors agreeing either concerning the names or offices which ought to be assigned to different parts of the generative apparatus. It must therefore be our endeavour, in considering this part of their economy, to separate as far as practicable all conjecture and hypothetical reasoning from the simple facts which anatomy has placed at our disposal, and leave disputed questions to be solved by careful experiment and research. According to the dissection of John Hunter, the internal generative apparatus is double, occupying both sides of the alimentary canal. Covering the stomach (fig. 235, *d*), there is found a vascular substance, which the above-named illustrious anatomist regarded as probably constituting the tubular parts of the testicle, from which a tortuous canal with very thick walls (*vas deferens*) runs upwards along the side of the intestine to the root of the fleshy prolongation (*k*), at which point it is joined by the corresponding tube from the opposite side of the body. The common canal thus formed is extremely slender, and passes in a flexuous manner through the whole length of the tubular organ (*k*), named by Hunter, apparently for the sake of brevity, the penis, to terminate by a minute orifice at its extremity. Yet, notwithstanding the name applied to the termination of the sexual canals, Hunter was well convinced that the Cirripeds were hermaphrodites,—as he expressly says *, "It is most probable that all Barnacles are of both sexes and self-impregnators; for I could never find two kinds of parts, so as to be able to say, or even suppose, the one was a female, the other male."

Fig. 235.



Anatomy of *Pentelasmis vitrea*: *a*, external envelope of the body; *b*, the mouth; *c*, the œsophagus; *d*, the stomach; *e*, *f*, tract of the intestine; *g*, bristle inserted into the anal orifice; *h*, the oviduct. (After Hunter.)

(1175.) Cuvier found the vascular mass, considered by Hunter as being the tubular portion of the testis, to be composed of granules, which he deemed to be ova; and conceived the delicate white vessel seen to ramify through the ovarian mass, as represented in the figure, to be the oviduct, whereby the eggs were taken up and conveyed into the thick and glandular canal (*h*), from the walls of which he imagined that a fecundating liquor might be secreted for the impregnation of the ova *in transitu*. He therefore regarded the proboscidiform tube (*k*) as an ovipositor, whereby the ova derived from both sides of the body are expelled. Before scattering them abroad, as Cuvier noticed, the animal retains them for a considerable length of time concealed between the body and the mantle, where they form two or three irregularly-shaped layers. When the eggs are found in this situation, he observed that the ovaria were empty and the testicles much less tumid—circumstances which indicate the season of oviposition to be at an end.

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* Descriptive and Illustrated Catalogue of the Physical Series of Comparative Anatomy in the Museum of the Royal College of Surgeons of England, vol. i. p. 259.

(1176.) In opposition to the views entertained by Cuvier concerning the generative process in the class before us, various continental writers consider the true ovary to be contained in the cavity of the tubular fleshy pedicle, which in *Pentelasmis* serves to fix the body to the substance whereunto it is attached. This, indeed, at certain periods, is found to be filled with oval granular bodies of regular shape, which are apparently real ova, diffused through the loose cellulosity enclosed within it; and these ova, being found in different states of maturity, are apparently secreted in the pedicle itself,—although some authors contend that, having been formed and impregnated in the manner indicated by Cuvier, they are conveyed into this situation by the ovipositor, as upon this assumption the prolonged organ (fig. 235, *k*) would be named. Other anatomists, again, regard the instrument last mentioned as being a real penis, and suggest that from its length it might even be introduced into the peduncular cavity itself, and thus effect the impregnation of the ova contained therein.

(1177.) It is to Mr. Darwin that science is indebted for a knowledge of the fact that in at least two genera of the Lepadidæ distinct male and female individuals exist; and for the far more wonderful discovery that in the same genera there exist hermaphrodite species, whose masculine efficiency is aided by one or two *complemental males*. In the genus *Ibla* for example, in one species, *I. Cumingii*, the egg-bearing individual is simply female, presenting no trace either of the external proboscidiform penis, or of the vesiculæ seminales, or of the testes; while, on the other hand, the ovarian tubes within the pedicle are developed in the usual manner, as are likewise the true ovaria at the upper edge of the stomach. But although there thus was a total deficiency of the usual male portion of the sexual apparatus, Mr. Darwin found attached within the sac, in a nearly central line (fig. 236, *h*), a flattened, purplish, worm-like little animal, which, notwithstanding its different appearance, turned out upon dissection to be, in reality, the male Cirriped belonging to this species, although totally dissimilar in its external configuration.

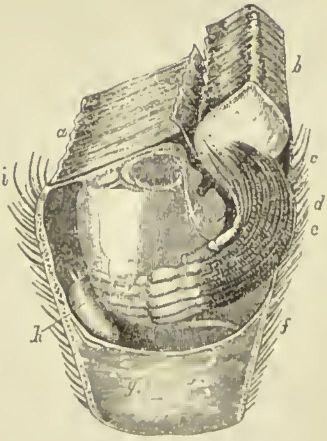
(1178.) The dimensions and proportions of the male animal vary much; but it is always exceedingly minute, the longest specimen measuring not more than $\frac{8}{100}$ths of an inch in length. The main part of the body consists of the peduncle, which tapers more or less suddenly towards its extremity, which latter is imbedded deeply in the integuments of the female, passing obliquely through the chitine-membrane and corium, and, running along amidst the underlying muscles and inosculating fibrous tissue; is attached to them by cement at the extremity.

(1179.) Within the muscular layer all round the upper part of the peduncle, and surrounding the stomach, the body of this minute creature contains numerous little, rather irregular, globular balls with brown granular centres, so closely resembling the testes in other Cirripedes as to leave little doubt that they are of the same nature. The vasa deferentia are plainly visible, occupying their normal situation; and the presence of spermatozoa is indisputable. The vasa deferentia unite and terminate under the two extremely minute caudal appendages: but there is no projecting proboscidiform penis; and in this case apparently the whole body, furnished like the penis with longitudinal and transverse muscles, serves the same purpose!

(1180.) Another species belonging to the same genus, *Ibla quadrivalvis,* furnishes an example of a hermaphrodite Cirriped, which might be supposed to be in itself sufficient for reproduction, provided with a complemental male,—an arrangement still more wonderful than that just described as existing in *I. Cumingii.* In the androgynous individual there is a penis, singularly constructed of several distinct segments, as well as the vasa deferentia and testes, which latter are unusually large and egg-shaped, while the ovigerous system is likewise completely developed; nevertheless in five out of six specimens dissected by Mr. Darwin males were present, in every respect similar in their structure to those of *I. Cumingii* described above, and of some of which he was enabled to trace the preparatory metamorphoses, common to the class, from their larval condition to the adult state.

(1181.) In this same hermaphrodite specimen of *Ibla quadrivalvis,* the two ovigerous lamellæ contained some hundreds of larvæ in the first stage of development, which were liberated from their enveloping membranes by a touch of a needle; they were about $\frac{16}{1000}$ths of an inch in length, and presented all the usual characters of larvæ at this period. What a truly wonderful assemblage of beings of the same species, exclaims the distinguished naturalist to whom we are indebted for these researches, did this individual hermaphrodite present! We have the numerous, almost globular larvæ, with lateral horns to their carapaces, with their three pairs of legs, single eye, proboscidiform mouth, and long tail: we have the somewhat larger larvæ,

Fig. 236.



Ibla Cumingii, showing the supplemental male: *a, b, c, d, e, f, g, i,* body of the female *Ibla*; *h,* supplemental male. (After Darwin.)

in the last stage of their development, much compressed, boat-formed, with their two great compound eyes, curious prehensile antennæ, closed rudimentary mouth, and six natatory legs, so different from those of the first stage: we have the attached males, with their bodies reduced almost to a mouth, placed on the summit of a peduncle, with a minute, apparently single eye shining through the integuments, without any carapax or capitulum, and with the thorax, as well as the legs or cirri, rudimentary and functionless: lastly, we have the hermaphrodite with all its complicated organization, its thorax supporting six pairs of multi-articulated two-armed cirri, and its well-developed capitulum, furnished with horny valves, surrounding this wonderful assemblage of beings. Unquestionably, without a rigid examination, these four forms would have been ranked in different families, if not orders, of the Articulated kingdom.

(1182.) The observations of Mr. Thompson* relative to the progress of the ova after their escape from the pedicle throw much additional light upon this portion of our subject. "In the whole tribe of Cirripeds," says this industrious naturalist, "the ova, after their expulsion from the ovarium, appear to be conveyed by the ovipositor into the cellular texture of the pedicle, just beneath the body of the animal, which they fill to the distance of about an inch. When first placed in this position, they seem to be amorphous, and inseparable from the pulpy substance in which they are imbedded; but as they approach to maturity they become of an oval shape, pointed at both ends, and are easily detached. Sir Everard Home has given a very good representation of them at this stage of their progress, in his 'Lectures on Comparative Anatomy,' from the elegant pencil of Mr. Bauer.

(1183.) "During the stay of the ova in the pedicle, they render this part more opake and of a bluish tint,—the ova themselves, and the cellular texture in which they are surrounded, being of a pale or azure-blue colour. It is difficult to conceive in what manner the ova are extricated from the situation above indicated; but it is certainly not by the means suggested by Sir E. Home in the above-mentioned lecture, viz. by piercing outwards through the membranes of the pedicle: for the ova are subsequently found forming a pair of leaf-like expansions, placed between either side of the body of the animal and the lining membrane of the shells. These leaves have each a separate attachment at the sides of the animal to the septum which divides the cavity occupied by the animal from that of the pedicle: they are at first comparatively small, having a rounded outline, and possess the same bluish colour which the ova had in the pedicle: but as the ova advance in progress, these leaves extend in every dimension, and lap over each other on the back, passing through various lighter shades of colour into pale pink, and finally, when ready to hatch, become nearly white.

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* Phil. Trans. for 1835, p. 356.

These leaves appear to be composed of a layer of ova, irregularly placed, and imbedded in a kind of parenchymatous texture, out of which they readily fall, when about to hatch, on its substance being torn asunder; indeed, it appears at length to become so tender as to fall entirely away, so that, after the period of gestation is passed, no vestige of these leafy conceptacles is to be found."

(1184.) In the second form of CIRRHOPODA (*Balani*), the animals, instead of being appended to foreign substances by elastic and flexible pedicles, are sessile,—the shelly investment of the body being in immediate contact with the rock or other submarine body to which the Barnacle adheres. The soft tube of *Pentelasmis* is, in this case, represented by a strong testaceous cone composed of various pieces accurately joined together, and generally closed inferiorly by a calcareous plate; while the representatives of the valves of the pedunculated species form a singular operculum, which is moved by special muscles, and accurately shuts the entrance of the shell when the animal retires into its abode. In their general structure, however, the Balaniform Cirrhopods accord with the description above-given; and, from the similarity of their habits and economy, a more elaborate account of the peculiarities which they exhibit would be superfluous in this place.

(1185.) One of the most remarkable circumstances connected with the history of the CIRRHOPODA is the recently-discovered fact of their undergoing a distinct metamorphosis; so that, in the earliest periods of their existence, instead of being rooted by means of a pedicle or otherwise, the newly-hatched young are endowed with locomotive organs calculated to enable them to swim freely about, and giving them rather the appearance of Entomostracous Crustacea than of animals of their own class. This singular fact was first announced by Mr. J. V. Thompson, of Cork*; and its correctness has since been admitted by various anatomists who have devoted their attention to this subject. Mr. Thompson's first observations were made upon minute animals, which, although at first actually taken for Crustaceans, turned out to be the young fry of *Balanus pusillus*; and the following is that gentleman's account of their appearance and subsequent change. The young Cirrhopod is a small translucent animal, $\frac{1}{10}$th of an inch long, of a somewhat elliptic form, but very slightly compressed laterally, and of a brownish tint. When in a state of repose, it resembles a very minute mussel, and lies upon one of its sides at the bottom of the vessel of sea-water in which it is placed; at this time all the members of the animal are withdrawn within the shell, which appears to be composed of two valves, united by a hinge along the upper part of the back, and capable of opening from one end to the other along the front, to give occasional exit to the limbs. The limbs are of two descriptions, viz.: anteriorly, a large and very strong pair provided with a cup-like sucker and hooks, serving solely to attach the animal to rocks, stones, &c.; and posteriorly, six pairs of natatory members, so articulated as to act in concert, and to give a very forcible stroke to the water, causing the animal, when swimming, to advance by a succession of bounds, after the same manner as the Water-flea (*Daphnia*) and other Monoculi, but particularly *Cyclops*, whose swimming-feet are extremely analogous. The tail, which is usually bent up under the belly, is short, composed of two joints, and terminates in four setæ, forming an instrument of progression. The animal, moreover, is furnished with large pedunculated eyes. After keeping several of the above for some days in sea-water, they threw off their exuviæ, and, becoming firmly adherent to the bottom of the vessel, were changed into young Barnacles; and the peculiarly-formed shells, with their opercula, were soon distinctly formed, while the movements of the cirri, although as yet imperfect, were visible. As the shell becomes more complete, the eyes gradually disappear, the arms become perfectly ciliated, and an animal originally natatory and locomotive, and provided with a distinct organ of sight, becomes permanently and immoveably fixed, and its optic apparatus obliterated.

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* Zoological Researches, 4th Memoir, 1830.

(1186.) Similar results were obtained by watching the development of the pedunculated type of Cirripeds* (*Lepades*), many of which were proved in their earliest form to resemble different kinds of Monoculi, and to be possessed of the capability of locomotion.

(1187.) The manner in which larvæ thus constituted are converted into the fixed and pedunculated Cirriped is, indeed, one of the most remarkable features connected with the history of the class. The larva in its last stage has much the appearance of one of the Stomapod Crustaceans; and, as is the case in several genera belonging to that order, the part of the head bearing the antennæ and organs of sense in front of the mouth equals or even exceeds in size the posterior part of the body, consisting of the enclosed thorax and abdomen. On the borders of the carapax at the anterior end, on the sternal surface, there are two minute orifices, sometimes having a distinct border round them, within which are contained minute sacculi, regarded as acoustic organs; and, moreover, large compound eyes, each consisting of eight or ten lenses, are situated near the bases of the antennæ.

(1188.) But it is the antennæ themselves that principally claim our notice, inasmuch as it is by means of these organs that the creature ultimately attaches itself when about to assume its complete or fixed condition. They consist of three segments; the first, or basal one, is much larger than the others†, and apparently always has a single spine on its outer distal margin. The second segment consists either of a large, thin, circular sucking-disk, or is hoof-like; in all cases it is furnished with spines on the exterior hinder margin. The third and ultimate segment is small; it is articulated on the upper surface of the disk,

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[*] Phil. Trans. for 1835, p. 355.

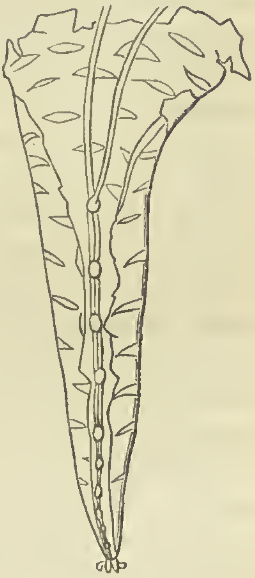
[†] Darwin, *loc. cit.*

and is directed rectangularly outward; it is sometimes notched, and even shows traces of being bifid, and bears about seven spines at the end, some of which are hooked, others simple. The antennæ, at first, are well furnished with muscles, and serve for the purpose of walking, one limb being stretched out before the other; but their main function is to attach the larva, for its final metamorphosis into a Cirriped, by means of the appended disk, which can adhere even to so smooth a surface as a glass tumbler*. The attachment is at first manifestly voluntary, but soon becomes involuntary and permanent, being effected by special and most remarkable means.

(1189.) In each of the antennæ there is situated a duct, derived from a large glandular body (the *cement-gland*): the termination of this duct is situated in the immediate vicinity of the adhesive disk, by the assistance of which the little animal is about to fix itself permanently to some foreign body and assume the Cirriped condition.

(1190.) Several times Mr. Darwin succeeded in dissecting off the integuments of the lately-attached larva, and in displaying the enclosed *Lepas* entire, of which, in this condition, he gives the following account:—Whilst tho young *Lepas* is closely packed within the larva, the capitulum (or shell-clad portion of the body), as known by the five valves, about equals in length the peduncle. The peduncle occupies the anterior half of the larva; and even at this early period the muscles of its inner tunic are quite distinct. The compound eyes, as we have already seen, are attached to the sternal surface of the larval carapax, and are consequently cast off with it: but the antennæ, which are not moulted with the carapax, are left cemented to the surface of attachment; their muscles are converted into sinewy fibres, the corium after a short timo is absorbed, and they are then preserved in a functionless condition. If, indeed, tho peduncle even of an adult Cirriped be very carefully removed from the surface of attachment, quite close to the end, but not at the actual apex, the larval prehensile antennæ can always be found, and the cement-ducts traced, running in a slightly sinuous course on each side within the peduncle, until they arrive at the glandular organs whence tho cement is furnished. Each gland contains a strongly coherent, pulpy, opake cellular mass, like that in the cement-ducts; and it is this peculiar substance that constitutes the bond of union between the Cirriped and the surface whereupon it becomes fixed.

Fig. 237.



Cement-ducts of *Scalpellum*, magnified.

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* Rev. R. L. King, Annual Report of the R. Inst. of Cornwall, 1848.

CHAPTER XVII.

HETEROGANGLIATA* (Owen).

Mollusca (Cuvier).

(1191.) The term Mollusca, employed by Cuvier to designate the fourth grand division of the animal world, is obviously derived from a very unimportant circumstance of their organization, which the tribes included in it possess in common with innumerable forms of very dissimilar beings, whose soft bodies are unsupported by any internal or tegumentary framework of sufficient density to merit the name of a skeleton. Subsequent anatomists have therefore, however unwillingly, been compelled to substitute another name for that given by the illustrious French zoologist to this extensive class, the boundaries and relations of which, as at present admitted, remain precisely as they were first established by his patient and unwearied investigations relative to the anatomical structure of the animals comprised within its limits.

(1192.) It is to the arrangement of the nervous system that we must again have recourse in order to discover a distinctive appellation; nor in this shall we be disappointed; for here we at once find a character peculiar to this great section of animated nature, and generally applicable to the various classes composing it. All the Mollusca present nervous ganglia, which, in the more highly organized forms, attain considerable development and consequent perfection; but these nervous centres, instead of being arranged in a longitudinal series of symmetrical pairs, are variously distributed in different parts of the body,—an arrangement exactly correspondent to the want of symmetry observable both in the external configuration of these creatures and in the anatomical disposition of their internal viscera. Still, however, one large ganglionic mass occupies a position above the œsophagus, and it is with this that the nerves of the existing senses invariably communicate; so that we are naturally induced to regard this as the sentient brain, corresponding with the supra-œsophageal ganglion of the Articulata both in position and office. The other ganglia vary considerably both in number and in situation; but, wherever placed, they all communicate with the supra-œsophageal mass, while the branches derived from them are distributed to the viscera, or to the locomotive organs.

(1193.) Various are the forms and widely different the relative perfection of the Mollusca, as regards their endowments and capabilities. Some, as the Polyzoa, fixed to the surface of foreign bodies, either immoveably or by the intervention of a flexible pedicle, entirely deprived of organs connected with the higher senses, and unable to change their position, are content to cast out at intervals their ciliated arms, which form a net of Nature's own contrivance, and thus entrap such passing prey as suits their appetite. Others, equally incapable of locomotion, but furnished with arms of different construction (BRACHIOPODA), catch their food by similar efforts. The TUNICATA, enclosed in coriaceous bags, are firmly rooted to the rocks; or, aggregated into singular compound masses, float at the mercy of the waves. The CONCHIFERA inhabit bivalve shells; while the GASTEROPOD orders, likewise defended in most cases by a shelly covering, creep upon a broad and fleshy ventral disk, and, thus endowed with a locomotive apparatus, exhibit senses of proportionate perfection. The PTEROPODA swim in myriads through the sea, supported on two fleshy fins; while the CEPHALOPOD MOLLUSCA, the most active and highly organized of this large and important division of animated nature, furnished with both eyes and ears, and armed with formidable means of destroying prey, become tyrants of the deep, and gradually conduct us to the most exalted type of animal existence.

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* ἕτερος, dissimilar; γαγγλίον, a ganglion.

(1194.) These different sections, which constitute, in fact, so many distinct classes into which the HETEROGANGLIATA have been divided by zoologists, we shall now proceed to examine *seriatim*; beginning, as heretofore, with the most imperfectly organized, and gradually tracing the development of superior attributes and more exalted faculties as the nervous centres attain greater magnitude and concentration.

CHAPTER XVIII.

POLYZOA (Thompson).

BRYOZOA[*] (Ehrenberg). CILIOBRACHIATE POLYPI (Farre).

(1195.) IT is only within the last few years that microscopical researches have revealed to naturalists the real structure of a series of animals originally confounded with the simpler polyps, with which, as far as external form is concerned, they are indeed intimately related. The observations of Milne-Edwards[†], Audouin, Ehrenberg[‡], and Thompson[§] gradually led the way to more correct and precise ideas concerning the more highly-organized genera; while Dr. Arthur Farre[||] and Van Beneden, by a series of investigations followed up with exemplary industry and perseverance, seem to have completed our knowledge of the anatomical details of these creatures in a manner which leaves few points of their economy unknown.

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[*] βρύον, sea-moss; ζῶον, an animal.

[†] Ann. des Sci. Nat. for Sept. 1828 and July 1836.

[‡] Symbolæ Physicæ.

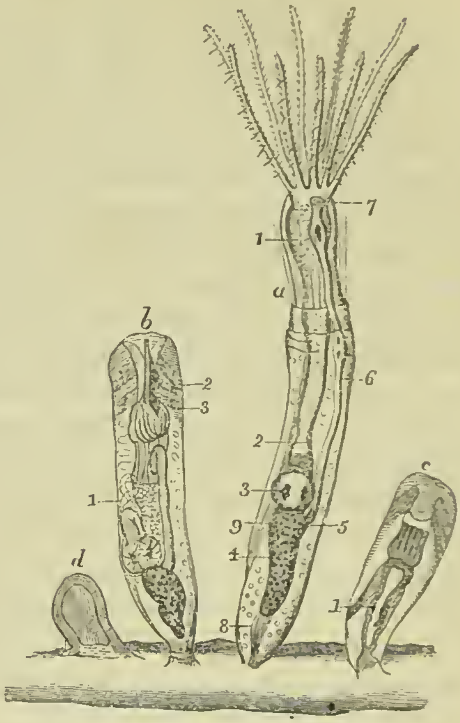
[§] Zoological Researches and Illustrations, Memoir 5. Cork, 1830.

[||] Phil. Trans., Part 2. for 1837.

(1196.) We shall select an individual, named by Dr. Farre *Bowerbankia densa,* as an illustration of the general structure of the Polyzoa, partly from the complete manner in which its organization has been developed in the memoir alluded to, and partly because we have had frequent opportunities of verifying the accuracy of the observations recorded.

(1197.) The tentacula of *Bowerbankia* (fig. 238) during the expanded state of the animal are kept quite straight and motionless, as represented in the drawing. Each tentacle is provided upon its outer aspect with a series of stiff and immoveable spines, probably serving to keep off any foreign bodies that by their proximity might interfere with the ciliary movements immediately to be described.

Fig. 238.



Anatomy of *Bowerbankia densa* (after Farre). *a*, The animal with its tentacula expanded:—1, pharynx; 2, œsophagus; 3, the gizzard; 4, the stomach; 5, the pylorus; 6, the intestine; 7, the anal aperture. *b* represents the Bryozoon retracted into its cell:—1, 2, 3, muscular fasciculi. *c*, An imperfect gemma before the opening of the cell:—1, stomachal cavity. *d*, A gemma sprouting from the common stem.

(1198.) Besides the stiff spines, the tentacula are covered with an immense number of vibrating cilia, which, at the will of the animal, are thrown into most rapid movement, so as to produce strong and continuous currents in the surrounding fluid, whereby particles floating in the neighbourhood are hurried along with great velocity. From the direction of the streams produced by the cilia, namely towards the mouth, we at once perceive the utility and beauty of the contrivance, compensating to a great extent for the fixed condition of the Polyzoon: animalcules floating in the vicinity no sooner come within the influence of the currents so produced than they are forced towards the mouth, situated in the centre of the tentacular zone, and, being at once seized, are immediately swallowed.

(1199.) The tentacula themselves, notwithstanding their immobility during the process of watching for prey, are highly irritable, and sensible of the slightest contact. No sooner does an animalcule impinge upon any part of their surface than the tentacle touched bends with extraordinary quickness, as if endeavouring to strike it towards the mouth; and if the object be sufficiently large to touch several at the same moment, all the tentacula simultaneously cooperate in seizing and retaining it.

(1200.) The existence of these cilia upon the tentacula would seem to be characteristic of the Polyzoa, and is invariably accompanied, as far as our information extends at present, with a digestive apparatus of far more complex structure than what we have seen in the unciliated polyps; for in the class before us, besides the stomach, there is a distinct intestinal tube and anal outlet. In the specimen under consideration the organization of the alimentary organs is rendered even more elaborate than is usual in the class, by the addition of a gizzard or cavity wherein the food is mechanically bruised before its introduction into the proper stomach. The mouth is placed in the centre of the space enclosed by the tentacula: it appears to be a simple orifice, incapable of much distention, through which the particles of food brought by the ciliary action pass into a capacious œsophagus (fig. 238, *a*, 1, 2); this, gradually contracting its dimensions, ends in a globular muscular organ, to which the name of gizzard has been applied (3). The walls of this viscus are composed of fibres that radiate from two dark points, seen in the figure; and its lining membrane is covered with a great number of hard horny teeth, so disposed as to represent, under the microscope, a tessellated pavement. The contractions of the gizzard are vigorous; and, from the structure of its interior, its office cannot be doubtful.

(1201.) To the gizzard succeeds a stomach (fig. 238, *a*, 4), which is studded with brown specks, apparently of a glandular nature, and probably representing a biliary apparatus. The intestine leaves the stomach at its upper portion, close to the gizzard (5), and, running parallel with the œsophagus towards the tentacula (6), terminates at the side of the mouth (7), in such a position that excrementitious matter is at once whirled away by the ciliary currents. The whole intestinal apparatus floats freely in a visceral cavity that contains a transparent fluid and encloses distinct muscular fasciculi, to be described in another place.

The process of digestion in this minute yet highly-organized being is well described by Dr. Farre in the memoir above-mentioned.

(1202.) The little animal, when in vigour, is seen projecting from its cell, with the arms extended and the cilia in full operation,—the upper part of the body being frequently turned from side to side over the edge of the cell, the extremity of which, from its peculiar flexibility, moves along with it. The particles carried to the mouth in the vortex produced by the action of the cilia, after remaining a little while in the pharynx, are swallowed by a vigorous contraction of its parietes, and carried rapidly down the œsophagus and through the cardia to the gizzard, that expands to receive them. Here they are submitted to a sort of crushing operation, the parietes of the organ contracting firmly upon them, and the two dark bodies being brought into opposition. Their residence, however, in this cavity is only momentary, and they are immediately propelled into the true stomach below, where they become mixed up with its contents, which, during digestion, are always of a dark, rich brown colour, being tinged with the secretion of its parietal follicles.

(1203.) The food appears to be retained for a considerable time in the stomach, and may be frequently seen to be regurgitated into the gizzard, whence, after having been again submitted to its operations, it is returned to the stomach. Here it is rolled about by the contraction of its parietes, and at its upper part is frequently submitted to a rotating motion. This rotation of particles is chiefly near the pyloric orifice; and a mass may be occasionally seen projecting through the pylorus into the intestine, and rotating rapidly in the direction of the axis of the orifice. In an animal having a similar form of pylorus to this, but in which the parts were more transparent, the cilia, by which this rotation is effected, were distinctly perceptible, surrounding the orifice.

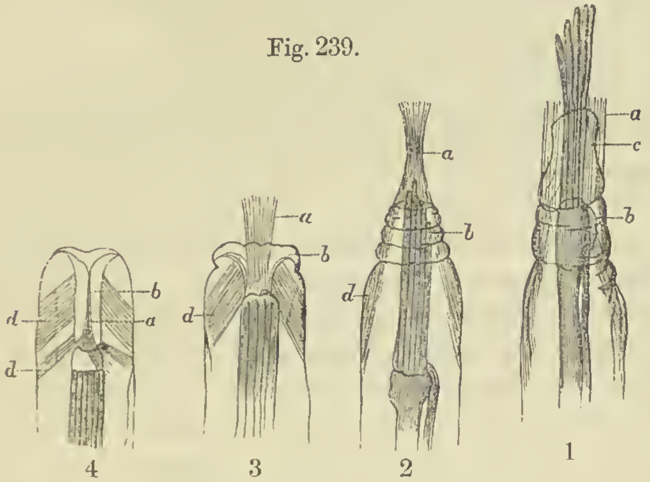
(1204.) The granular matter, after rotating for some time at the pylorus (a provision for preventing its too rapid escape from the stomach), passes into the intestine, where it accumulates in little pellets, that are rapidly pushed, by the contraction of the intestine, towards the anal orifice, through which they are expelled from the body.

(1205.) The tube or cell inhabited by this Polyzoon is of exquisite structure, and the mechanism concerned in the protrusion and retraction of the animal of great simplicity and beauty.

(1206.) The inferior two-thirds of the cell in the species under consideration is hard and corneous, but perfectly transparent: the upper third, on the contrary, is flexible, and so constructed as to form a very complete operculum whereby the entrance is guarded. The flexible part consists of two portions, the lower half being a simple continuation of the rest of the cell, while the upper is composed of a circle of delicate bristle-shaped processes or setæ, which are arranged parallel to each other around the mouth of the cell, and are prevented from separating beyond a certain distance by a membrane of excessive tenuity that connects them; this membrane is evidently analogous to the infundibular termination of the cells of polyps already described.

(1207.) When the Polyzoon retires into its abode, the setæ and soft termination of the cell are gradually folded inwards, in the manner exhibited in the annexed figures (fig. 239) representing the various stages of the process. The œsophagus, surmounted by its tentacula, descends first, whilst the integument of the upper part of the body begins to be inverted at the point where it has its insertion around the base of the tentacles (*c*). As the descent of the tentacula proceeds, the inversion of this membrane continues; and when the extremities of the arms have reached the level of the extremities of the setæ, it is seen to form a complete sheath around them. The animal being thus retracted, the next part of the process is to draw-in the upper portion of the cell after it. The setæ are now brought together in a bundle (fig. 239, 2, *a*) and are gradually drawn inwards, inverting around them the rest of the flexible portion of the cell, until they form a close fasciculus (fig. 239, 3 & 4, *a*) occupying the axis of the opening of the tube, constituting a complete protection against intrusion from without.

Fig. 239.



Bowerbankia, showing the opercular apparatus.

(1208.) The muscular system exhibits the earliest appearance of muscular fibre. The filaments are unconnected by cellular tissue, and have a watery transparency and smooth surface; neither do they exhibit cross markings, or a linear arrangement of globules, even when examined under the highest powers of the microscope.

(1209.) The muscles may be divided into two sets:—one for the retraction of the alimentary apparatus; the other acting upon the setæ around the mouth of the cell, and serving for the inversion of its flexible portion. The bundles of muscular fibre which act upon the alimentary canal are two in number, and arise from near the bottom of the cell: one of these is inserted into the stomach (fig. 238, *a*, 8); the other passes upwards along the side of the œsophagus (fig. 238, *a*, 9), to be attached in the vicinity of the tentacula: the latter fasciculus is evidently the great agent in drawing the animal into its retreat, and in doing so it throws the alimentary canal into close sigmoid folds.

(1210.) The muscles that close the operculum are arranged in six distinct fasciculi; they arise from the inner surface of the upper hard part of the cell, and act upon the upper flexible portion of the tube and upon the setæ (fig. 239, *d d*).

(1211.) The mode in which the protrusion of the tentacula is effected is not so easily explained; it would seem that the lining membrane of the shell is furnished with circular muscular fibres, so disposed as by their action to compress the fluid contained in the visceral cavity, and thus tend to elongate the body. Dr. Farre, however, believes the alimentary canal itself to be the great agent in effecting this object; and he conceives it to possess a power of straightening itself from the flexures into which it is thrown during the retracted state of the animal.

(1212.) The FLUSTRÆ and ESCHARÆ are intimately allied to *Bowerbankia* in all the details of their structure, as we are assured by the researches of Dr. Milne-Edwards concerning these singularly aggregated forms of marine Polyzoa*.

(1213.) The cells of the *Flustræ* and *Escharæ* are disposed side by side upon the same plane, so as to form a common skeleton of a coriaceous or horny texture. The individual cells, which are extremely minute, vary in shape in different species; and the orifice of each is generally defended by projecting spines, or sometimes by a moveable operculum, or lid, that closes the orifice in the contracted state of the animal. The extension of one of these skeletons is effected by the regular addition of new cells around the circumference of the *Flustra*, those of the margin being, of course, the most recent; and the latter are not unfrequently found inhabited by healthy animals, whilst in the older or central ones the original occupants have perished.

(1214.) The facts observed by Milne-Edwards relative to the formation of these cells possess a high degree of interest, and materially support the views already given concerning the formation of the tubes of zoophytes in general, proving that the calcareous matter to which their hardness is owing is not a mere exudation from the surface of the animal, but is deposited in an organized tegumentary membrane, whence it can be removed with facility by means of extremely dilute muriatic acid. When so treated, a brisk effervescence is produced; the cells become flexible, and are easily separated from each other: but they are not altered in form, and evidently consist of a soft and thick membrane, forming a sac containing the digestive organs of the creature. In this state the opening of the cell is no longer defined as it was before, but the membranous cell appears continuous with the tentacular sheath. We see, therefore, that in these creatures the cell is an integral part of the animal itself—not a mere calcareous crust moulded upon the surface of the body—being a portion of the tegumentary membrane, which, by the molecular deposit of earthy matter in its tissue, ossifies, like the cartilage of higher animals, without ceasing to be the seat of nutritive movement. It is evident, likewise, that what is called the body of the Polyzoon constitutes, in fact, but a small portion of it, principally consisting of the digestive apparatus.

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* "Recherches Anatomiques, Physiologiques, et Zoologiques sur les Eschares" (Ann. des Sci. Nat. for 1836).

(1215.) As to the operculum destined to close the entrance of the tegumentary cell, it is merely a lip-like fold of the skin, the marginal portion of which acquires a horny consistence, while at the point where it is continuous with the general envelope it remains sufficiently soft and flexible to obey the action of the muscles inserted into it.

(1216.) The tegumentary sac, deprived of its carbonate of lime, seems to be formed of a tomentose membrane, covered, especially upon its outer side, with a multitude of cylindrical filaments disposed perpendicularly to its surface and very closely crowded together. It is in the interstices left by these fibres that the calcareous matter appears to be deposited; for if a transverse section be examined with a microscope, the external wall is seen not to be made up of superposed layers, but of cylinders or irregular prisms arranged perpendicularly to the axis of the body.

(1217.) But the above are not the only arguments adduced by Milne-Edwards in confirmation of this view of the mode in which these skeletons are held in vital connexion with the animal. On examining the cells at different ages, it is found that they undergo material changes of form.

(1218.) This examination is easily made, since in many species the young spring from the sides of those first formed, and do not separate from their parents; each skeleton therefore presents a long series of generations linked to each other, and in each portion of the series the relative ages of the individuals composing it are indicated by the position which they occupy. It is sufficient therefore to compare the cells situated at the base, those of the middle portion, those of the young branches, and those placed at the very extremities of the latter. When examined in this manner, not only is it seen that the general configuration of the cells changes with age, but also that these changes are principally produced upon the *external surface*. For instance, in the young cells of *Eschara cervicornis* (the subject of these observations), the walls of which are of a stony hardness, the external surface is much inflated, so that the cells are very distinct, and the borders of their apertures prominent; but by the progress of age their appearance changes, their free surface rises, so as to extend beyond the level of the borders of the cell, and defaces the deep impressions which marked their respective limits. It results that the cells cease to be distinct, and the skeleton presents the appearance of a stony mass, in which the apertures of the cells only are visible.

(1219.) It appears evident therefore that there is vitality in the substance composing the stony walls; and the facts above narrated appear only explicable by supposing a movement of nutrition like that which is continually going on in bone.

(1220.) The anatomy of these Polyzoa differs slightly from that of *Bowerbankia.* The crown of ciliated tentacula is inserted into the extremity of a kind of proboscis, which is itself enclosed in a cylindrical retractile sheath. From the margin of the opening of the cell arises a membrane equalling in length the contracted tentacles, and serving to enclose them when the animal retires into its abode. These appendages, thus retracted, are not bent upon themselves, but perfectly straight and united into a fasciculus, the length of which is nevertheless much shorter than that of the same organs when expanded.

(1221.) By the opposite extremity to that fixed to the margin of the opening of the cell, the tentacular sheath unites with a tolerably capacious tube, the walls of which are exceedingly soft and delicate; and near the point of their union we may perceive a fasciculus of fibres running downwards to be inserted upon the lateral walls of the cell: these fibres appear to be striated transversely, and are evidently muscular; their use cannot be doubted. When the animal wishes to expand itself, the membranous sheath above alluded to becomes rolled outwards, everting itself like the finger of a glove as the tentacles advance. The muscular fasciculi are thus placed between the everted sheath and the alimentary canal, and by their contraction they must necessarily retract the whole within the cell.

(1222.) The first portion of the alimentary tube is inflated, and much wider than the rest; it forms a kind of chamber, in which the water set in motion by the vibration of the cilia upon the tentacles appears to circulate freely. The walls of this chamber are extremely delicate: the soft membrane forming them is puckered, and appears traversed by many longitudinal canals united by minute transverse vessels; this appearance, however, may be deceptive.

(1223.) Beneath the first enlargement, the digestive apparatus becomes narrower, but immediately expands again, and offers at this point a certain number of filiform appendages, which appear to be free and floating in the interior of the cell. To the second cavity succeeds a narrow canal, opening into a third dilatation, generally of a spherical form. From the last-named viscus issues a kind of intestine, which soon bends upon itself and becomes attached to an organ of a soft and membranous texture, having the appearance of a cæcum, and which seems to be continuous superiorly with the digestive tube; the latter continues its progress towards the upper part of the cell, and ultimately terminates by a distinct anal aperture upon the upper aspect of the tentacular sheath.

(1224.) The operculum which closes the cell in *Flustræ* and *Escharæ* is moved by two muscular fasciculi inserted into the internal face of this valve by the intermedium of two filaments analogous to tendons; by their inferior extremity these muscles are attached to the walls of the cell; and when, by its own elasticity, the operculum is turned back, and the mouth of the cell thus opened, they, by their contraction, can close it like a door.

(1225.) The existence of nervous ganglia has been satisfactorily detected in many genera of the Polyzoa : it consists of a nervous ganglion, situated immediately above the œsophagus, from each side of which proceeds a nervous cord forming a collar around that tube, as well as other filaments distributed to the muscular system.

(1226.) No organ of special sensation has been discovered in any animals of this class, either in their adult state, or during the earlier periods of their development.

(1227.) From what is known concerning the propagation of the Polyzoa, it would appear that their reproduction is effected in several different ways.

(1228.) The most ordinary is by the development of gemmæ, or buds, that sprout from the parent stem in the branched species, or, as in the *Flustræ* and *Escharæ*, are derived from the sides of contiguous cells.

(1229.) In *Pedicellina Belgica*, the phenomena attending the gemmiparous mode of reproduction are the following* :—First, there sprouts from the common stem of the Polyzoon, without any determinate situation, a minute tubercle, which is simply a prolongation from the stem itself; this tubercle gradually extends outwards, becomes more prominent, and soon swells into a vesicle, which is the first appearance of the new individual. Up to this period the interior of the vesicle is organized precisely in the same manner as the stem itself, of which it is only an extension; but now a cellule becomes visible in its centre, which forms the point of departure whence the development of the embryo proceeds.

(1230.) Around this primitive cell a series of other very small cellules soon group themselves, which seem to constitute the parietes of the primitive vesicle, or blastoderm, the original cell representing the vitelline cavity. The bud now enlarges; and as its growth proceeds, the internal tissue becomes thickened, so as to fill it completely; subsequently an indentation becomes apparent on each side of the little cavity, separating the embryo into two halves, the inferior of which will form the stomach, the superior the intertentacular chamber.

(1231.) In *Laguncula repens*, the reproductive gemmæ sprout from the creeping stems which connect the individual animals, appearing at first as a slight prominence that soon expands into a rounded tubercle, which is the commencement of a new cell. On close inspection, each gemma is found to consist of a transparent envelope, that is, in fact, a continuation of the general investment of the animal, lined throughout with a soft membrane, having its inner surface studded with minute globules, by the accumulation of which the polyp is ultimately formed. The bud itself is hollow, and communicates with the parent stem: it therefore has nothing in its composition resembling that of an egg; neither distinct vesicle nor vitellus. The newly-formed cell soon grows taller, and its lining membrane becomes thicker, indicating the first appearance of the intestinal canal, which is at first a simple cavity bounded by the thickened lining of the cell. This cavity once formed, the development of the different organs proceeds rapidly. First there appears a longitudinal fold, resembling two lips, that, as they approach each other, divide the cavity of the body into an anterior and posterior compartment. The two lips, which have a valvular appearance, become very regularly indented along their margins, and are soon recognizable as the rudiments of the tentacular circle.

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* Van Beneden, "Recherches sur l'Anatomie, la Physiologie, et la Développement des Bryozoaires qui habitent la Côte d'Ostende" (Bulletin de l'Acad. Roy. de Bruxelles, tom. xix.).

(1232.) At this epoch, it must be remarked, the polyp presents two cavities distinct from each other: there is a space between the walls of the body and the parietes of the future alimentary canal, the interspace being in communication with the stem of the parent polyp, and filled with a fluid that is analogous to the blood of higher animals; superiorly this cavity likewise passes into the tentacles, and the fluid which bathes the exterior of the alimentary canal thus finds admission even to the extremities of those organs. The second cavity, which is the intestinal canal, has as yet no communication with the external world. As the formation of the tentacles proceeds, the portion which is situated in front of them will become the sheath, and the other part the intestine. As the tentacula are formed by the prolongation of the tubercles, which were their first rudiments, the cavity of the stomach and the rest of the intestinal tube gradually become apparent; and at the same time some globules are visibly disposed around the *cul de sac* of the former viscus, which gradually become arranged into fibrillæ, and constitute the retractor muscles.

(1233.) When the cell has nearly reached its full development, its parietes become softened, and an opening is formed, which brings the young polyp into communication with the surrounding element. The Polyzoon has now attained its complete form, and can expand its tentacula; but, as yet, there are no traces of a generative apparatus, which seems to be matured at a subsequent period.

(1234.) Reproduction is likewise effected, in the Polyzoa, by means of true ova. The ovary in which these are developed is situated immediately above the stomach, and is generally found containing eggs in different stages of growth. In the same vicinity is situated another viscus, regarded by Van Beneden as the testes, his opinion being founded on the fact that, when a mature specimen of the animal is placed between two plates of glass and gently compressed, so as to rupture its parietes and cause the escape of the viscera, spermatozoa are easily discoverable in its interior.

(1235.) The spermatozoa exhibit considerable vivacity in their movements, have a disk-like body and a caudal filament, and are proportionately of large size. Around them may be seen multitudes of free cellules without caudal appendages, which are apparently young spermatozoa. In some individuals the spermatozoa are so numerous that the intestinal canal appears completely enveloped by them, and the whole periintestinal cavity seems alive with their movements.

(1236.) In the mature ovary may be seen ova in different states of development, in each of which the vesicles of Wagner and Purkinje are distinctly visible. In ova approaching their complete maturity, an external vitelline membrane, or chorion, and a vitellus are perceptible, but the two vesicles above-mentioned have disappeared.

(1237.) When arrived at the proper term, the ova break from their envelope, or ovisac, and escape into the general cavity of the body, where they move freely about, surrounded on all sides by spermatozoa. At length the eggs accumulate in the interior of the parent, near the base of the tentacula; and their expulsion is ultimately accomplished in the following manner, through a special orifice in the immediate vicinity of the anus:—When an ovum is thus about to escape, its external membrane is first seen to protrude partially through the aperture, constituting a sort of hernia; the vitellus then gradually flows from the still enclosed portion of the egg into that which is external; and when the vitellus has thus entirely passed out, the egg is found separated from the parent animal, and falls into the surrounding water. These eggs are entirely destitute of external cilia, and are carried off by any casual current to attach themselves where chance may bring them; they are also remarkable for the irregularity of their shape, their form seeming to depend upon the pressure they have been subjected to in the interior of their parent.

(1238.) In *Pedicellina*, Professor Van Beneden has witnessed the escape of upwards of twenty eggs from a single individual. They are of a pyriform shape, and are enclosed in a pellucid membrane, by the intervention of which they adhere to each other, so that, in the interior of the body of the parent Polyzoon, they have a racemose appearance, and when extruded spontaneously are generally united together in pairs. Between the vitellus and the envelope of the egg there is always a small quantity of a transparent whitish fluid, which doubtless represents the albumen, while the pellucid external membrane itself is the chorion.

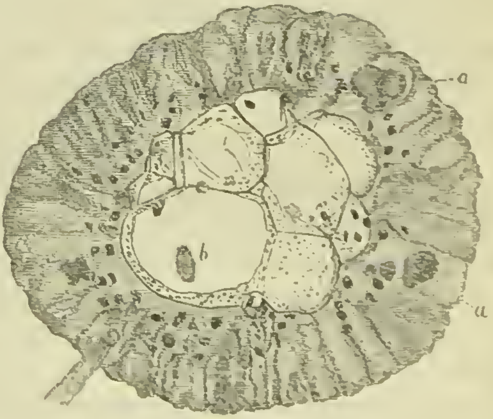
(1239.) The vitellus breaks up into granules, at first of large size, and afterwards, by subdivision, of smaller and smaller dimensions, giving a tuberculated appearance, like that of a raspberry, to the mass. This division seems to be accomplished exactly as in the ova of the higher animals, the yelk first separating into two, then into four, after which its breaking up proceeds rapidly.

(1240). The embryo enclosed within the egg at first presents a rounded form, but soon becomes divided by an indentation into an anterior and posterior moiety, and vibratile cilia become apparent upon the anterior extremity. That portion upon which the cilia have made their appearance next insensibly enlarges, and assumes the shape of a funnel, while the long cilia with which it is fringed begin to keep the particles suspended in the water around in rapid motion. The margins of the funnel rapidly extend themselves; the body exhibits frequent contractions, and at the end of about two hours little tubercles are apparent upon its anterior extremity, which subsequently become developed into the tentacula. Professor Van Beneden thinks that when the tentacula have become developed and furnished with their proper vibratile apparatus, the original cilia disappear. The formation of the tentacula at once indicates which are the two extremities of the body, and the point by which the embryo will subsequently attach itself.

(1241.) The embryo, when mature, is quite free, and strikingly resembles some forms of Infusoria; but after a while a pedicle is formed, whereby it proceeds to fix itself to some foreign body, and thus permanently assumes the aspect of its race. The pedicle seems to be formed from a cell, developed below the stomach, which grows directly outwards, and thus completes the organization of the young Polyzoon.

(1242.) A third form of reproduction is that by *ciliated gemmules*, common in *Halodactylus diaphanus* and other similar species having soft and fleshy or gelatinous polyparies. These are readily seen in spring, when they appear as minute whitish points imbedded in the substance of the mass; sometimes, however, they are of a dark-brown colour, and exceedingly numerous, appearing to occupy almost the entire substance of the polypary (fig. 240). If one of these points be carefully turned out with a needle and examined, it is found to consist of a transparent sac, in which are contained generally from four to six of the gemmules, which, as soon as the sac is torn, escape, and swim about with the greatest vivacity*. Sometimes they

Fig. 240.



Thin transverse section of *Halodactylus diaphanus*. The centre occupied by cellular tissue and water; the circumference formed by cells in close approximation: the brown bodies scattered through the substance. *a a*, Position of the gemmules enclosed in their sac; *b*, one of the gemmules escaped during the section of the central tissue.

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[*] Dr. A. Farre, Phil. Trans. 1837, p. 140.

simply rotate upon their axis, or they tumble over and over; or, selecting a fixed point, they whirl round it in rapid circles, carrying every loose particle with them; others creep along the bottom of the watch-glass upon one end, with a waddling gait; but generally, after a few hours, all motion ceases, and they are found to have attached themselves to the bottom of the glass. At the expiration of forty-eight hours, the rudiments of a cell are observable, extending beyond the margin of the body; but any account of their further development is still a desideratum.

(1243.) We have hitherto only spoken of those Polyzoa whose habitat is the sea; besides the marine genera, there are, however, many individuals belonging to this class that abound in fresh water. The polyparies of the FLUVIATILE POLYZOA are met with in ponds and streams, adherent to any foreign bodies which may be casually submerged*. Thus, they are found attached to stones at the bottom of the water; upon the shells of *Anodon*, *Unio*, and other freshwater mollusca; upon leaves, more especially those of the Water-lily (*Nymphæa*) and of the Bistort (*Polygonum amphibium*); upon floating wood; upon the stems of *Arundo phragmites* and of various other plants. Some genera (*Alcyonella* and *Fredericella*) frequently agglomerate into masses of considerable size, such as might be mistaken for spongillæ. The *Paludicellæ* often form an inextricable interlacement of filaments, spread out over shells and stones. *Cristatella* and *Lophopus* are generally met with upon the stem of some aquatic plant, such as the Brook-lime (*Veronica beccabunga*), resembling, when examined by the naked eye, a layer of fluid albumen, which might easily be mistaken for the eggs of *Limnæus stagnalis*. In order to examine these animals in a living state, it is necessary to leave the leaf to which they are attached for some time undisturbed in a glass of clear water, when they will soon be seen spreading forth their beautiful tentacula as they protrude from their delicate cells. By frequently changing the water, more especially if it is rich in *Naviculæ* and *Bacillariæ*, they may be kept alive for months, affording objects of continual interest for the microscope.

(1244.) In the freshwater Polyzoa the structure of the external envelope is similar to that of the marine species, except that in no instance are the fluviatile genera known to possess a calcareous polypary.

(1245.) In *Cristatella mucedo*† (fig. 241, 3) the polypary or external envelope (*d*) is membranous and slightly cordiform, its surface is tuberculated, and it is incapable of contraction. In this outer covering several individuals are contained; but although produced from one another, they are only aggregated, being lodged in distinct tubular cells. The body of each animal appears to consist of a digestive canal constricted once or twice in its course, and terminated by an anal orifice. When these creatures are extended, the upper part of the body protrudes from the cell, the tentacular apparatus being supported on a kind of neck, whereon the mouth (*a*) is easily seen, and near it the anus.

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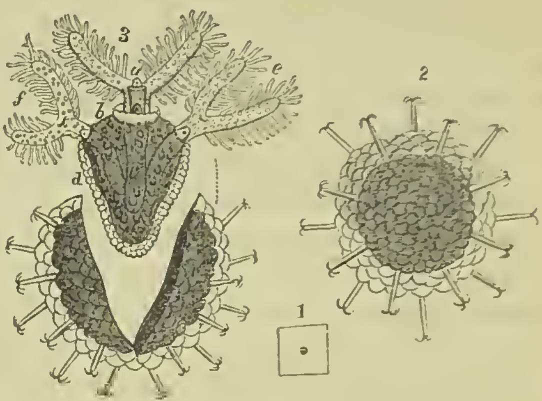
* "Recherches sur les Bryozoaires fluviatiles de Belgique," par P. J. Van Beneden (Nouv. Mém. de l'Acad. de Bruxelles, 1847).

† M. Turpin, "Etude microscopique de la *Cristatella mucedo*, espèce de polype d'eau douce" (Ann. des Sci. Nat. for 1837). Also, another memoir upon the same subject by M. P. Gervais (*ibid.*).

Fig. 241.



Cristatella mucedo. 1. Egg, natural size. 2. Egg, magnified. 3. Animal after its escape from the egg: *a*, the mouth; *b*, openings of cell; *c*, the stomach; *d*, shell; *e*, *f*, ciliated tentacula.

(1246.) On each side of the mouth the body divides into two arms, which, when spread out, resemble a horse-shoe, being flattened and blunt; and upon the arms are arranged about a hundred slender, transparent, retractile tentacles, disposed on each side and upon the summit like the barbs of a feather, and all covered with an infinite number of cilia, whose action produces currents directed towards the mouth, hurrying in that direction organized particles contained in the water.

(1247.) The three individuals that thus inhabit the same general covering are produced at two distinct generations—the two lateral being the offspring of the central one, derived from it by a process of gemmation; but, when complete, they are evidently quite separate from and independent of their parent.

(1248.) The number of the tentacular appendages varies very considerably in different genera: in *Paludicella* and *Fredericella*, which have the fewest, there are about twenty, while in *Alcyonella*, *Plumatella*, and *Cristatella* (fig. 241) there are as many as sixty, or even more. In *Paludicella* the arrangement of the tentacula is infundibular; but in *Lophopus*, *Alcyonella*, *Plumatella*, and *Cristatella* (fig. 241) they assume the shape of a horse-shoe. In *Fredericella* (fig. 242) they are united together for one-half of their length by means of a delicate membrane.

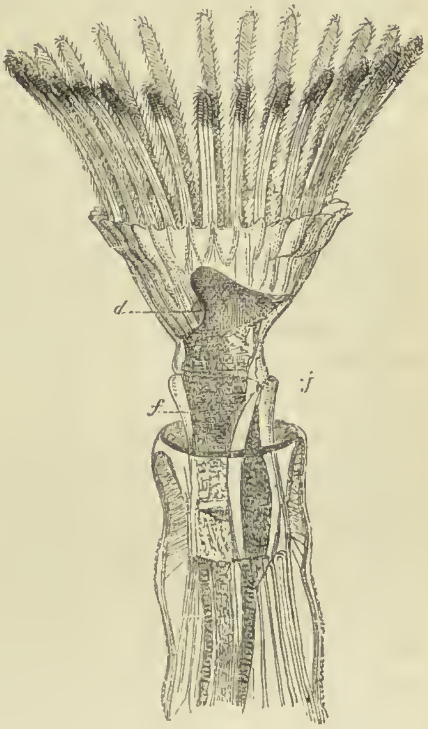
(1249.) The digestive apparatus in all these different genera consists of an œsophagus, of a stomach, which forms a *cul de sac*, and intestinal tube. The intestine is always straight, and without convolutions. Its cavity is separated from that of the stomach by a pyloric valve that completely closes the aperture; whilst the œsophagus is in like manner provided with a fold, situated sometimes near its middle, sometimes at its lower part, that performs the office of a cardiac valve.

(1250.) The aliments, before admission into the stomach, accumulate in a cavity formed at the commencement of the digestive tube (fig. 242, *f*), which in most genera is defended by a largely developed lip (*d*) that opens and shuts like a valve; this lip is densely covered with cilia, the action of which is very energetic.

(1251.) The anus (*j*) is always situated at the base of the tentacular zone.

(1252.) The food of the fluviatile Polyzoa consists of Infusorial animalcules and the microscopic Desmidieæ which abound in the waters they frequent, and whose remains are distinguishable both in their stomachs and in the contents of the intestine. They are likewise easily made to swallow carmine, sepia, and other colouring substances.

Fig. 242.



Fredericella sultana: *d*, mouth; *f*, pharynx; *j*, anal orifice.

(1253.) There seems to be no doubt relative to the nature of the circulation in these animals. The place of blood seems to be altogether supplied by the chylaqueous fluid. This fluid is not contained in vessels, unless the cavities of the tubular tentacula be considered as such, but moves freely in all directions around the parietes of the digestive canal. There is consequently neither heart nor any vascular system,—the chylaqueous fluid, which thus represents the blood, being kept in continual movement in the periintestinal cavity by the action of the cilia that cover the exterior of the intestinal apparatus. It is therefore ciliary action that determines the course of the aliment in the interior of the alimentary apparatus, and of the fluid external to its walls—the cilia thus answering the purpose of a heart as well as of the muscular coat of the intestines.

(1254.) All the viscera of the body being thus bathed by the chylaqueous fluid that surrounds the intestinal canal, they receive directly, through the intermedium of that fluid, both the materials for nourishment and the means of respiration.

(1255.) Reproduction among the freshwater Polyzoa is accomplished in two ways—by gemmation and by true ova. The first of these modes resembles exactly what has been described as existing among the marine genera; but as regards the process of oviparous reproduction, there are some remarkable points of difference that require notice.

(1256.) It is now generally understood that, wherever oviparous reproduction occurs, there is a formation of spermatozoa; and modern observations have proved the existence of these distinguishing products of the male sex in most genera of the ciliobrachiate polyps. Frequently both the sexes are conjoined, so that there is a complete hermaphroditism; but in some cases the sexes are separate, and the number of female individuals is greater than that of the males. Seeing that among these compound animals the blood, or its representative fluid, is common to an entire group, and that the ova as well as the spermatozoa are diffused through this liquid before they are evacuated, a single male individual may, strictly speaking, suffice for the fecundation of the eggs of a whole colony.

(1257.) But with regard to the ova themselves, a remarkable difference is observable between those of the fluviatile and of the marine Polyzoa. Among the *Alcyonellæ* and other genera there exist two sorts of eggs—the one covered with vibratile cilia, capable of swimming freely about exactly like Infusorial animalcules, and the other enclosed in a hard shell, having somewhat the appearance of the seeds of some plants. The first sort, without a shell, is also met with among marine species; but the second seems peculiar to the freshwater Polyzoa. In *Cristatella mucedo*, for example, the ova are of this latter description, being enclosed in a dense horny shell, the exterior of which is covered over with sharp hooklets, giving them an appearance strikingly like some of the Desmidieæ (fig. 241, 2). This shell is probably intended to preserve the ova during the winter season from being destroyed by the freezing of the ponds in which they occur, while the marine polyps, being subjected to no such changes of temperature, can dispense with such a covering. It is on this account apparently that these ova are met with sometimes naked, and sometimes provided with a shell; and in the same way, in the genus *Paludicella* (in which ova have not been detected), the gemmæ become invested on the approach of winter with a horny covering.

(1258.) As there are thus two modes of reproduction, so are there two kinds of embryogenic development observable among the fluviatile Polyzoa; that is to say, the polyp which is produced from an egg is formed in a different manner from that which is produced by the process of gemmation. In the mature ovum, both the germinal spot and the germinal vesicle are distinctly perceptible; but in the nascent gemma the existence of neither of these elements is to be detected. According to the gemmiparous mode of propagation, the young individual is formed by direct extension from the tissues of the parent. In the formation of the embryo from an egg, there is, from the first, a complete isolation of the newly-formed progeny: a vesicle or cell is formed, which, previous to its conversion into a new individual, requires the cooperation of another cell, or, in other words, the ovum remains unproductive unless brought in contact with the male fluid containing spermatozoa, whereas in gemmiparous reproduction such a concurrence is by no means necessary; neither germinal vesicle nor any male apparatus is required.

CHAPTER XIX.

TUNICATA*.

(1259.) The singular class of Mollusca to which the name at the head of this chapter has been applied is at once distinguished by the remarkable character afforded by the texture of the external investment of the body. In their general organization the Tunicata are very nearly allied to the ordinary inhabitants of bivalve shells, with which, both in the structure and arrangement of their viscera, they correspond in many particulars; but instead of being enclosed in any calcareous covering, a strong, flexible, cartilaginous or coriaceous integument forms a kind of bag encasing their entire body, and only presenting two comparatively narrow orifices, through which a communication with the exterior is maintained.

(1260.) Various are the forms under which these animals present themselves to the eye of the naturalist; but the enumeration of them will be more conveniently entered upon hereafter. We shall therefore at once lay before the reader the principal points connected with the structure and habits of an *Ascidia* belonging to one of the most perfectly organized families; and after examining this attentively, our descriptions of allied genera will be rendered more simple and intelligible. The Ascidians are abundantly met with upon the shores of the ocean, especially at certain seasons of the year. In their natural condition they are found fixed to the surfaces of rocks, sea-weed, or other submarine bodies: frequently, indeed, they are glued together in bunches; but in this case individuals are simply agglomerated, without organic union. Incapable of locomotion, and deprived of any external organs of sense, few animals seem more helpless or apathetic than these apparently shapeless beings, and the anatomist is surprised to find how remarkably the beauty and delicacy of their interior contrasts with their rude external appearance. In the species selected for special description (*Phallusia nigra*), the external envelope (fig. 243, *a a a*) is soft and gelatinous in its texture, fixed at its base to a piece of coral (*l*), and exhibiting at its opposite extremity two orifies (*h*, *f*), placed upon prominent portions of the body. Through the most elevated of these orifices (*h*) the water required for respiration and the materials used as food are taken in, while the other (*f*) gives egress to the ova and excrementitious matter. The soft outer covering is permeated by blood-vessels, which ramify extensively in it; it is moreover covered externally with an epidermic layer, and lined within by a serous vascular membrane, which, in the neighbourhood of the two orifices, is reflected from it on the body of the animal lodged inside. The creature hangs loosely in its outer covering, to which it is only connected at the two apertures by means of the reflexion of the peritoneal membrane above mentioned.

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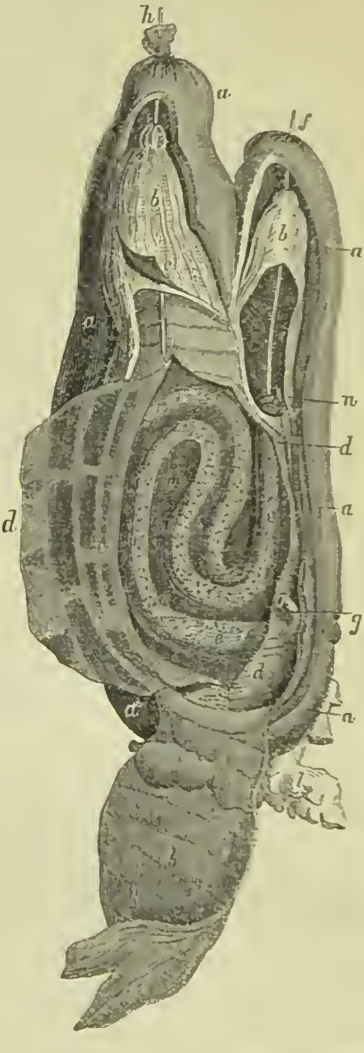
* *Tunicatus*, clad in a tunic.

Fig. 243.



Structure of *Phallusia nigra*: *a a a*, external envelope; *b b*, the mantle; *c*, mantle reflected so as to display *d d*, the membrane lining the respiratory sac; *e e*, alimentary canal; *f*, excretory orifice; *g*, orifice of oviduct; *h*, oral aperture; *l*, a piece of coral to which the animal is fixed; *n*, the anus. (After Hunter.)

(1261.) On removing a portion of the exterior tunic, that in reality represents the shells of a bivalve Mollusk, the soft parts of the Ascidian are displayed. The body is seen to be covered with a muscular investment (the *mantle*) (fig. 243, *b b*, *c*), composed of longitudinal, circular, and oblique fibres, which cross each other in various directions, so as to compress by their contraction the viscera contained within, and this so forcibly that, when alarmed, the animal can expel the water from its branchial sac, immediately to be described, in a thin continuous stream, sometimes projected to a distance of many inches.

(1262.) Respiration is effected in an apparatus of very peculiar contrivance, to the examination of which we must now request the attention of the student. A considerable portion of the interior of the body is occupied by a circumscribed cavity, that opens externally by the orifice *h*; into this bag a bristle has been introduced in the dissection, represented in the figure (fig. 243); its walls are seen to be composed of a thin but very vascular membrane (*d d d*), that has been partially turned back, so as to display the interior of the respiratory sac. The membrane (fig. 243, *d d d*; fig. 244, *c*), when examined with a microscope, is found to be covered with a magnificent network of blood-vessels, formed by innumerable canals uniting with each other at right angles; and moreover, when seen in a living state, its surface is discovered to be densely studded with vibratile cilia, whose rapid action constantly diffuses fresh supplies of water over the whole vascular membrane. The respiratory cavity has but one orifice for the admission of water (fig. 244, *a*), and this is guarded by a fringe of delicate and highly sensitive tentacula (fig. 244, *b*); so that the water, as it is drawn into the body, having necessarily to pass these tactile organs, any foreign substances which it might contain of a prejudicial character are at once detected and denied admission. All the vascular ramifications spread over the lining membrane of the branchial chamber are connected with two sets of large vessels; one of which, receiving the blood from the body, disperses it over the spacious respiratory surface; while the other, collecting it after it has undergone exposure to the respired medium, conveys it in a pure state to the heart.

(1263.) The heart itself presents the simplest possible form, being generally a delicate elongated contractile tube, receiving at one extremity the blood derived from the numerous vessels that ramify over the interior of the branchial sac, whilst at the opposite end it becomes gradually attenuated into the aorta, through which it impels the circulating fluid and disperses it through the system.

(1264.) The heart, above described, is extremely thin and transparent, and is lodged in a distinct pericardium, which separates it from the other viscera.

(1265.) Notwithstanding this apparently simple arrangement of the vascular system in the Ascidians, the nature of the circulation of the blood, throughout the class, is extremely curious, the action of the heart being completely reversed at brief intervals, and the course of the blood entirely changed—a phenomenon which is easily witnessed in any of the smaller and more transparent species, when placed under the microscope. The contractions of the heart succeed each other with regularity; but they are sluggish, not extending at once through the whole organ. The systole commences at one extremity, and is propagated by an undulatory movement towards the opposite end by a sort of peristaltic action. For some time the contractions succeed each other with rapidity, passing on in the same course, when they suddenly cease, and, after a pause, recommence from the other end of the viscus. The blood, thus impelled alternately from behind forwards, and then in the contrary direction, ascends towards the branchial apparatus; nevertheless it does not appear to be conducted there by closed vessels, but seems to be diffused between the inner tunic of the abdomen and the viscera, where it flows in currents that vary in their direction as the movements of the animal, or any other mechanical causes, affect their passage. The chief portion of the blood, however, ascends by the dorsal or the ventral surface of the abdomen, and, after having bathed the surface of the viscera, gains the base of the branchial sac. When the contractions of the heart are directed forwards, the ascending current of blood passes along the anterior wall of the abdominal cavity and enters a capacious sinus, situated in front of the respiratory chamber, which gives origin on each side to a series of large transverse vessels; and these intercommunicating with each other by means of innumerable branches disposed vertically, a rich vascular network is formed, that, after spreading all over the walls of the branchial cavity, pours its blood into another vertical sinus situated at the opposite side of the thoracic cavity, into which is likewise poured the vitiated blood derived immediately from the system. Lastly, the circulating fluid, again diffusing itself between the viscera, descends along the dorsal region of the abdomen and again reaches the heart. Were the circulation constant in the above direction, as Milne-Edwards observes, it would somewhat resemble that of other Acephalous Mollusca. The heart might then be compared to an aortic ventricle, and the anterior thoracic sinus to a branchial vein. But, owing to the contrary directions of the currents of blood, due to the changing action of the heart, the vessels that during one minute perform the functions of veins, are in the next converted into arteries.

(1266.) When we consider the fixed and immoveable condition of an Ascidian, and its absolute deprivation of all prehensile instruments adapted to seize prey, it is by no means evident, at first sight, how it is able to subsist, or secure a supply of nourishment adequate to its support; neither is the structure of the mouth itself, or the strange position which it occupies, at all calculated to lessen the surprise of the naturalist who enters upon the consideration of this part of its economy. The mouth, in fact, is a simple orifice, quite destitute of lips or other extensible parts, and situated, not at the exterior of the body, but at the very bottom of the respiratory sac (fig. 243, and fig. 244, *g*). It is obvious, then, that, whatever materials are used as aliment, they must be brought into the body with the water required for respiration: but even when thus introduced into the branchial cavity, the process by which they are conveyed to the mouth and swallowed still requires explanation. We have before noticed that the interior of the branchial chambor is covered with multitudes of vibratile and closely-set cilia, well described by Mr. Lister*, which, by their motion, cause currents in the water. When these are in full activity, observes that gentleman in the paper referred to, the effect upon the eye is that of delicately-toothed oval wheels, revolving continually in a direction ascending on the right, and descending on the left of each oval, as viewed from without; but the cilia themselves are very much closer than the apparent teeth; and the illusion seems to be caused by a fanning motion given to them in regular and quick succession, which produces the appearance of waves; and each wave answers here to a tooth.

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* Phil. Trans. for 1834, p. 378.

(1267.) Whatever little substances, alive or inanimate, the current of water brings into the branchial sac, if not rejected as unsuitable, lodge somewhere on the respiratory surface, along which each particle travels horizontally, with a steady, slow course to the front of the cavity, where it reaches a downward stream of similar materials; and they proceed together, receiving accessions from both sides, and enter at last the œsophagus, placed at the bottom (fig. 244, *g*), which carries them, without any effort of swallowing, towards the stomach.

Fig. 244.

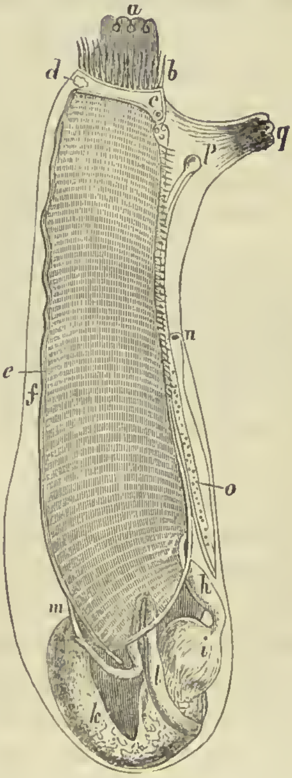

Diagram of an Ascidian, showing the position of the viscera: *a*, the oral orifice; *b*, tentacula guarding it; *c*, *d*, nervous ganglia; *e*, respiratory sac; *f*, longitudinal vessel; *h*, *i*, *k*, *l*, *m*, stomach and intestine; *o*, ovary; *p*, termination of oviduct; *q*, common excretory orifice.

(1268.) The œsophagus (fig. 244, *h*) is short, and internally gathered into longitudinal folds. The stomach (*i*) is simple, moderately dilated, and has its walls perforated by several orifices, through which the biliary secretion enters its cavity. The liver is a glandular mass intimately adherent to the exterior of the stomach and the intestinal canal (fig. 243, *e e*), of variable length, and, more or less convoluted in different species, after one or two folds terminates in the rectum, which, emerging from the peritoneal investment covering the intestine, has its extremity loosely floating in the cavity communicating with the second orifice (*f*): into the latter a bristle is introduced in the figure, having its extremity inserted into the anal extremity of the digestive tube. Excrementitious matter, therefore, when discharged from the rectum, escapes from the body through the common excretory aperture, generally situated upon the least elevated protuberance of the outer covering*. It would seem that the food of Ascidians consists of very minute particles of organized matter; for although small Crustacea and other animal remains have been occasionally met with in the branchial chamber, nothing of this nature has been observed in the stomach itself; and, as must be obvious to the reader, the oral aperture seems but little adapted to the deglutition of bulky substances.

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* Cuvier, Mémoire sur les Ascidies, p. 14.

(1269.) The reproductive system in these humble forms of Mollusca presents the utmost simplicity of parts, being composed of an ovarian nidus, in which the germs of their progeny are elaborated, and a duct, through which their expulsion is accomplished.

(1270.) The researches of Milne-Edwards*, however, relative to this part of their economy, tend to show that the structure of these creatures is more complex than was previously supposed; and in *Amaroucium Argus*, one of the compound Ascidians, that indefatigable observer also succeeded in recognizing the presence of a male apparatus. This consists of a largely-developed testicular gland, that occupies almost all the lower part of the post-abdomen, and communicates with the common excretory cavity by means of a long filiform canal that was regarded by Savigny as the oviduct. This gland is made up of a multitude of whitish vesicles, which, at first sight, have much the appearance of rudimentary eggs, but which, in reality, are found to swarm with spermatozoa, thus revealing the true nature of the organ. A similar arrangement has since been detected in numerous other genera; so that its existence throughout the entire class is now no longer doubtful. The ovarium is situated in close juxtaposition with the testes. In all the Polyclinian group it is lodged in the post-abdomen, and posteriorly is hardly distinguishable from the male apparatus, but towards the upper part becomes easily recognizable in consequence of the size and colour of the ova contained within it. The eggs, of which a few only are developed at a time, as they issue from the ovigerous organ pass immediately into the cloaca, or even become lodged in the lateral part of the thoracic chamber, between the proper tunic of this cavity and the branchial sac, where they remain for some time exposed to the influence of the surrounding aërated medium.

(1271.) Whilst the ova remain enclosed in the upper part of the post-abdomen, they increase considerably in size and assume a spherical form; the yelk acquires a deep-yellow colour; and the vesicle of Purkinje, which was distinctly visible during the commencement of their development, disappears, and is replaced by a cloudy spot, which appears to be the blastoderm, or proligerous layer, from which proceeds the embryo of the young Ascidian.

(1272.) During incubation the egg acquires more of an oval form, the vitelline mass seems to contract, and its surface, growing denser, appears to become organized into a membrane which is distinct from the more deeply-seated substance of the yelk, and gradually the whole becomes moulded into something like the shape of a tadpole (fig. 245, A), the anterior extremity of which is surmounted with a sort of tentacular apparatus; and on the bursting of the egg, this embryo, by means of its long tail, swims about in the water with considerable vivacity; after the lapse of a few hours, however, the little creature, in size not yet larger than the head of the smallest pin, fixes itself to some foreign object by means of one of the little suckers situated on the anterior extremity of its body, and permanently loses all capability of locomotion.

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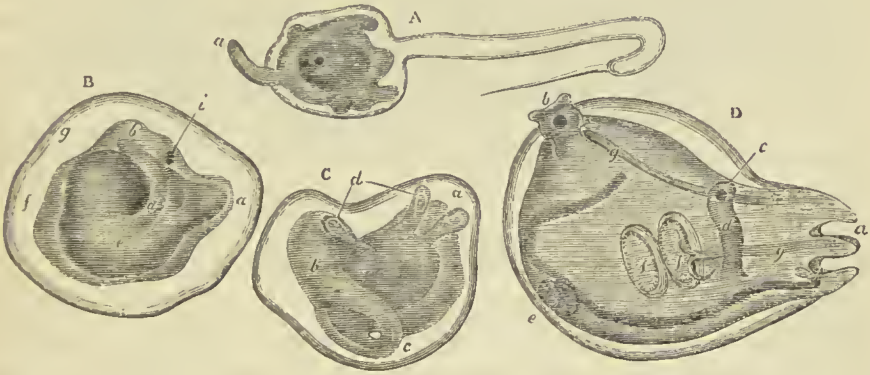
* "Observations sur les Ascidies composées," Mém. de l'Acad. tom. xviii.

(1273.) Having thus fixed itself for life, the larval Ascidian soon begins to change its form (fig. 245, B). The anterior extremity of its body becomes expanded, the tentacular appendages disappear, the central portion of the tail becomes retracted into the central mass, and, lastly, the tail itself, which was at first such an important locomotive agent, gradually withers away, until no traces remain of such an organ having existed (fig. 245, C, D).

Fig. 245.



Larva and progressive stages of metamorphosis in an Ascidian Mollusk.

(1274.) From the above description of the development of the young Ascidians, it appears that during the first part of their existence they are solitary and isolated animals, although at a later period they are found united into numerous colonies, either connected together by means of a creeping common stem, or associated into a compact mass by a tegumentary tissue wherein the entire colony is arranged after a certain order, or regular pattern, which is constant in each species; and the manner in which this is effected thus presents itself as a problem possessing considerable interest.

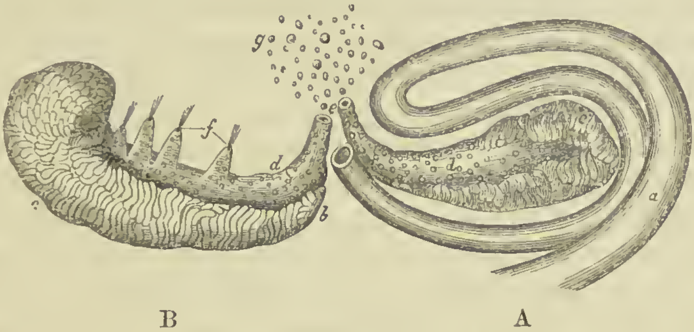
(1275.) Savigny, while prosecuting his dissections of the *Botrylli*, had remarked, situated upon the borders of the stellate groups formed by the association of individuals belonging to that genus, a multitude of membranous tubes, slightly dilated at their extremities, to which he gave the name of the *marginal tubes*, at the same time pointing out their existence in other families, but without entering into any details concerning the relations existing between them and the associated Ascidians contained in the tegumentary mass. Milne-Edwards, however, ascertained, by the examination of transparent groups of these creatures whilst in a living state, that each of these canals is at first a little tubercle, developed from the surface of the abdominal portion of the inner tunic of an adult Ascidian. This tubercle becomes elongated by growth into a tube, the extremity of which is closed, but free, while its internal cavity communicates freely by the opposite end with the abdominal cavity of the Ascidian from which it originally sprouted; so that the blood circulating in the latter easily penetrates into the cæcal appendage, wherein an active circulation is kept up. Generally speaking, in proportion as these marginal tubes advance into the common tegumentary tissue around them, they divide into several branches, and the extremity of each of them becomes inflated and claviform; soon there appears, towards the summit of each terminal swelling, a small granular mass wherein the forms of an Ascidian gradually develope themselves, and which in time becomes a new animal, resembling those already existing in the common mass, of which it is destined itself to become a new inhabitant. Ultimately the communication between the parent and the young individual becomes obliterated; but still the newly-formed animals, thus derived from the same parent, remain for some time united by their pedicle; and, apparently, to this circumstance their mode of arranging themselves in groups is due.

(1276.) The ovary is a whitish glandular mass, imbedded with the liver among the folds of the intestine; its position in fig. 243 is indicated by the letter *m*; and at *o*, fig. 244, it is seen separated from the surrounding structures. Tho oviduct, which is occasionally very tortuous, accompanies the rectum, and terminates near the anal aperture (fig. 243, *m*, fig. 244, *p*); so that the ova ultimately escape through the common excretory orifice.

(1277.) Since the publication of the former editions of this work. important additions have been made to our knowledge relative to the generative system of the class under consideration, and a distinct male apparatus, the existence of which was formerly denied, has been satisfactorily described by many skilful observers. The arrangement of these organs, as they exist in *Cynthia ampulla*, dissected by Van Beneden. is shown in the accompanying figure (fig. 246, A, B). In this species the sexual parts appear at first sight to form but a single organ, imbedded in a fold of the alimentary canal (*a*, *b*); but by the assistance of a microscope, this is readily seen to consist of two portions—one male, and the other female. The testicle (*c*) surrounds the base of the ovary. and is distinguishable by its milky-white colour; its substance is entirely made up of innumerable short convoluted cæca, visible to the naked eye. and resembling the seminiferous tubes of many of the higher animals. Three or four glandular prolongations (*f*) arise from the surface of this organ, which are hollow internally, and contain a milky fluid which is poured into the cloaca, and which the microscope reveals to be almost entirely composed of spermatozoa with disciform heads and filamentary tails. The ovary is of a dark colour, and is imbedded, as it were, in the testes; its oviduct (*e*) opens into the cloaca by the side of the anus.

(1278.) In *Ascidia grossularia*, the eggs, as seen through the walls of the ovary, are of a fine red colour, and are contained in separate sacs; so that the ovary when distended resembles a bunch of grapes. By the side of the ovary is another series of sacculi (fig. 246, B, *b*), the contents of which abound with spermatozoa, intimating their identity with the male apparatus above described.

Fig. 246.



Generative system of *Cynthia ampulla*.

(1279.) Deprived as these animals are of any of the higher organs of sense, and almost cut off from all relation with the external world, we can look for no very great development of the nervous centres. There is one ganglion, however, lodged in the substance of the mantle, distinctly recognizable, situate in the space between the branchial and excretory openings, from which large nerves are given off; but of other details connected with the nervous system of the Tunicata little has been made out.

(1280.) In the seas of tropical latitudes, many forms of Tunicated Mollusca are met with abundantly which, although allied to Ascidians in the main points of their economy, present certain peculiarities of structure that require brief notice in this place. These, grouped by authors under the general name of *Salpæ*, are many of them so transparent that their presence in a quantity of sea-water is not easily detected; and their viscera, if coloured, are readily distinguishable through their translucent integument, which in texture seems to be intermediate between cartilage and jelly. The body is oblong, and open at both extremities, the posterior opening being very wide, and furnished with a crescentic valve, so disposed that water is freely drawn into the interior through this aperture, but cannot again be expelled by the same channel; so that, being forced by the contractions of the body in powerful gushes from the opposite end, it not only supplies tho material for respiration, but impels the delicate animal through the water in a backward direction. The branchial chamber of *Ascidia* is consequently in this case represented by a wide membranous canal, which traverses the body from end to end; but, instead of the network of vessels lining the respiratory sac of Ascidians, a singular kind of branchial organ is placed within it. This consists of a long vascular riband attached by both its extremities to the walls of the canal, through which the water rushes; and of course, being freely exposed to the influence of the surrounding medium, the blood contained in this curious branchial apparatus is perpetually renovated, and afterwards distributed, by a heart resembling that met with in the genus last described, to all parts of the body.

(1281.) The viscera, which occupy comparatively a very small space, are lodged in a distinct compartment between the membranous respiratory channel and the external gelatinous investment, or soft shell, as we might properly term it. The mouth is a simple aperture, situated near the upper extremity of the branchial organ; and probably, as in *Ascidia*, ciliary currents rushing over the respiratory surface bring into it a sufficient supply of nutritive molecules. The stomach is capacious, and covered with parallel rows of large white filaments, that seemingly represent the liver; and the alimentary canal, which is perfectly simple, runs to the posterior extremity of the animal, and terminates there by a wide opening*. Two oblong bodies, each consisting of a granular substance, are seen upon the ventral surface of the body, lodged between the external and internal membranes; these, no doubt, are the ovaria, and form a reproductive system as devoid of complication as that of the sessile Ascidians.

(1282.) A very remarkable feature in the history of these animals is that many species are found swimming together in long chains, apparently adhering to each other by little suckers, but without organic connexion; and, what is still more strange, it would appear, from the observations of M. de Chamisso†, that such aggregated animals give birth to insulated individuals of very different appearance, which in their turn reproduce concatenated forms resembling their progenitors; so that the alternate generations are quite dissimilar both in conformation and habits.

(1283.) The observations of Chamisso have in later times been substantiated and carried out by the researches of Krohn, Steenstrup, Eschricht, Milne-Edwards, and others; and the phenomena connected with the process are so interesting that it will be necessary to lay before the reader a brief abstract of the result of their labours.

(1284.) The *Salpæ* are all viviparous, and each species is propagated by an alternate succession of generations most dissimilar from each other in their forms, habits, and mode of increase. The concatenated Salpæ produce but a single egg apiece, which is distinctly visible in the interior of their transparent bodies; they seem, moreover, to be bisexual, having, as it would appear, two generative functions to perform—the one to produce a new being, the other to fecundate a future generation of animals similar in all respects to themselves. But whilst the isolated Salpians are thus produced from eggs, their progeny are produced by a process of gemmation, springing like buds from the surface of a most remarkable organ, the *stolon prolifer*, the existence of which is to be detected in the isolated Salpæ even while contained in the body of their concatenated parent; it then appears a slender filament, derived by one extremity immediately from the heart of the embryo Tunicary; after birth, however, its growth increases apace in proportion to the development of the continual succession of progeny to which it gives origin. The reason of the immediate connexion between the "stolon proliferum" and the maternal heart appears to be this, that the newly-formed offspring being entirely dependent for support upon the blood of the parent, it is so situated in order to secure a free supply of the vital fluid, which is thus injected into its vessels immediately by the heart's action. Two vessels traverse it throughout its entire length, one derived from the anterior extremity of the maternal heart, and the other from its opposite end; so that the blood supplied to one of these vessels by the contraction of the heart is returned by the other; and when the contractions of the heart become reversed, as we have seen is continually the case by this arrangement, the circulation in these vessels is readily adapted to the change. It is from the surface of the *stolon* that the generation of concatenated Salpæ sprout, in two parallel rows, appearing in rapid succession like so many little buds, which, as their growth advances, gradually assume a similar form and structure; and as successive groups become mature, detaching themselves from the nidus where they had their birth, they swim away united in long chains, the links of which are joined together after the fashion of the species. On examining one of these chains of concatenate Salpæ, the individuals composing it are found to be united to each, not by any organic coalescence, but by special organs and facets of attachment, frequently, but improperly, described as suckers, the position of which varies in different species in accordance with their mode of aggregation. It would appear, from the observations of M. Krohn, that the concatenated Salpæ cannot spontaneously detach themselves from each other, and that, when individuals are met with swimming free, their separation from the chain is always to be ascribed to accidental violence; he even thinks that concatenation is so essential to the existence of the animals that they soon perish if separated from the rest.

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* For excellent drawings representing the anatomy of various *Salpæ*, the reader is referred to the Descriptive and Illustrated Catalogue of the Physiological Series of Comparative Anatomy contained in the Museum of the Royal College of Surgeons of England, vol. i. plates 6 & 7.

† Dissert. de Salpâ, Berlin, 1830.

(1285.) The last families of Tunicata which we have to notice would seem to constitute a connecting link between the Ascidians and the Polyzoa, which latter in many points of their anatomy they much resemble. These animals generally are exceedingly minute, and individually present an organization analogous to that of Ascidians. At first it would appear that they are detached from each other, and, like

Salpæ, are endowed with a power of locomotion ; but subsequently they become aggregated in groups, either incrusting foreign bodies, or else, uniting together to form a mass of definite shape, they seem to enjoy, to a certain extent, a community of action. They are arranged by Cuvier[*] in three principal groups, distinguished by the following characters. In the first (*Botryllus*[†]), the little bodies of the individual animals are ovoid ; but they fix themselves upon the exterior of sea-weed or other substances in regular bunches, consisting of ten or twelve, arranged like the rays of a star around a common centre. The branchial orifices in such are all placed around the circumference of the star, while the excretory apertures open into a common cavity in the centre. If the external orifice is irritated, the animal to which it belongs alone contracts ; but if the centre be touched, they all shrink at once.

(1286.) In *Pyrosoma*[‡], the second family, the animals are aggregated together in great numbers, so as to form a hollow cylinder, open at one end, but closed at the opposite, which swims in the sea by the combined contractions and dilatations of all the individuals composing it. The branchial sacs here open upon the exterior of the cylinder, while the anal orifices are in its internal cavity. Thus a *Pyrosoma* might be described as consisting of a great number of stars of *Botrylli* piled one above the other, the whole mass remaining free and capable of locomotion. Many of these moving aggregations of Tunicata emit in the dark a most brilliant phosphorescent light, whence the derivation of the name by which they are distinguished.

(1287.) In all other forms of these aggregated Mollusca, which are designated by the general name of *Polyclinum*[§], as in ordinary Ascidians, the anus and branchial orifices are approximated, and placed at the same extremity of the body. They are all fixed ; some spreading like fleshy crusts over submarine substances, others forming conical or globular masses, or occasionally so grouped as to produce an expanded disk resembling a flower or an Actinia ; but, whatever the general arrangement of the common mass, it is composed of numerous associated individuals, every one of them corresponding more or less closely, as regards their internal structure, with the description above given of the organization of Salpæ and Ascidians.

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[*] Règne Animal, vol. iii. p. 168.

[†] *βότρυς*, a bunch of grapes.

[‡] *πῦρ* (-ὸς), fire ; *σῶμα*, a body.

[§] *πολὺς*, many ; *κλίνη*, a bed.

CHAPTER XX.

CONCHIFERA (Lamarck).

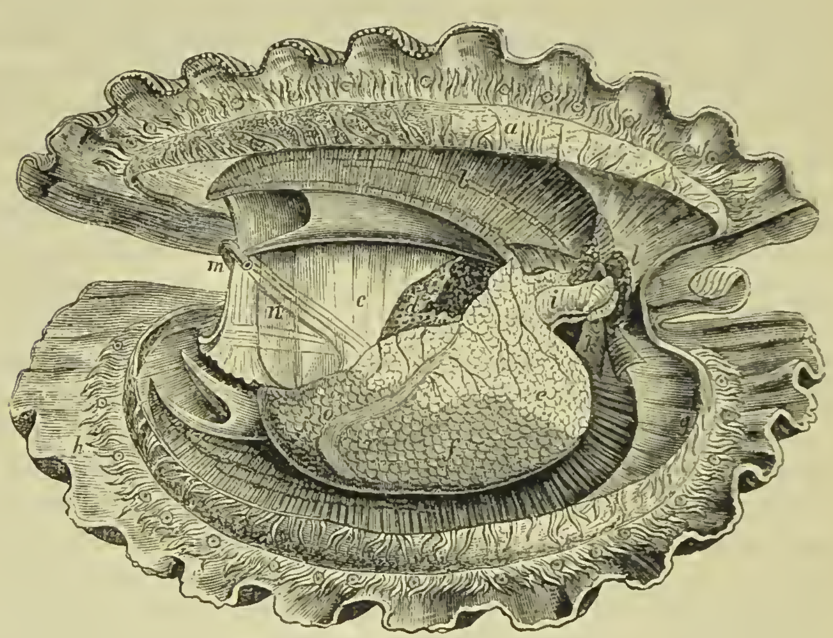
ACÉPHALES TESTACÉS (Cuvier).

(1288.) THE great majority of Mollusks which inhabit bivalve shells constitute a very numerous and extensive class, distinguished by certain characters possessed by them in common. Encased in dense and massive coverings of such construction as to preclude the possibility of their maintaining more than a very imperfect intercourse with the external world, and deprived even of the means of communication with each other, we might naturally expect their organization to correspond in its general feebleness with the circumscribed means of enjoyment and limited capabilities of locomotion allotted to them. Numerous species, indeed, are from the period of their birth firmly fixed to the rock which gives them support, by a calcareous exudation that cements their shells to its surface, as is familiarly exemplified in the case of the common Oyster; or else, as the Mussels, anchor themselves securely and immoveably by unyielding cables of their own construction. The Scallop, unattached, but scarcely better adapted for changing its position, rudely flaps together the valves of its expanded shell, and thus by repeated jerks succeeds in effecting a retrogressive movement; while the Cockles, destined to burrow in the sand, are furnished with a tongue-like foot, by which they dig the holes wherein they lie concealed, and crawl, or even leap about, upon the shore. Many, as the *Pholades,* penetrate the solid rocks and stones, and excavate therein the caverns that they inhabit; or, in the case of the *Teredo,* with dangerous industry bore into the bottoms of ships or submerged wood of any description, and silently destroy by their insidious ravages the piers or dykes which human labour has erected.

(1289.) Following our usual custom, we shall select for examination one of the most simply organized bivalves for the purpose of illustrating the general structure which characterizes the class; and in the common Scallop (*Pecten Jacobæa*) we have a species well adapted to exhibit the principal features of their economy. On separating the two valves of the shell in the animal before us, we at once perceive that each is lined internally with a thin and semitransparent membrane (fig. 247, *a*, *h*), which, like the shells, encloses the body of the mollusk in the same way that the leaves of a book are contained between its covers. The circumference of these outer membranes, which form the *mantle,* is, in this case, quite free and unconnected, except in the immediate vicinity of the hinge that unites the two valves. The borders of the mantle are thickened, and surrounded with a delicate fringe of retractile filaments;

they moreover present a decidedly glandular appearance, and secrete colouring matter of various tints, similar to those seen upon the exterior of the shell: the glandular margins of the mantle form, in fact, the apparatus by which the extension of the shell is effected; and by them its outer layer is secreted, and in many cases painted with gorgeous hues, as will be explained more at length hereafter.

Fig. 247.



Pecten Jacobæa.

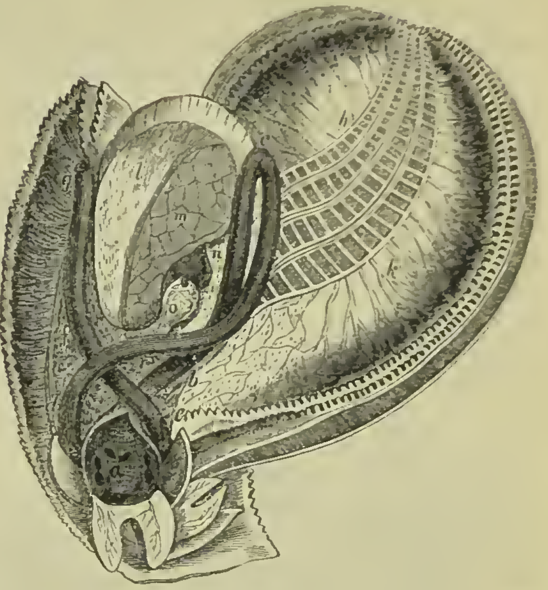
(1290.) Between the lobes of the mantle are seen the branchiæ (*b, g*), always consisting of four delicate leaves, composed of radiating fibres of exquisite structure, and generally attached to the circumference of the body by their fixed extremities, but elsewhere perfectly free, so as to float loosely in the water, which finds free admission to them. The mouth (*l*) is situated between the two inner laminæ of the branchiæ, in a kind of hood formed by the union of the gills at their origin; it is a simple orifice, without any kind of dental apparatus, but bordered by four thin and membranous lips (*k*) placed on each side of the aperture.

(1291.) The valves, which are opened by the elasticity of a compressible ligament interposed between them at the hinge, are closed by the contraction of a powerful muscle (*c*), which passes directly from one to the other, and around this adductor muscle the viscera of the body are disposed: the stomach, liver, and generative system are imbedded in the mass (*d, e, f*); the convolutions of the intestine may be traced occasionally (*n, o*); and the termination of the rectum (*m*) is visible externally, situated upon that side of the adductor muscle which is opposite to the mouth. In the neighbourhood of the oral aperture is placed a retractile fleshy organ (*i*), which, although in *Pecten* it exhibits very rudimentary dimensions, expands in other species to such a size as richly to merit the name of *foot* usually applied to it.

(1292.) Whoever for a moment reflects upon the arrangement of the branchial apparatus, and the position of the oral orifice, consisting, as it does, of a simple aperture unprovided with any prehensile organs, must perceive that there are two circumstances connected with the economy of a Conchiferous Mollusk, and those not of secondary importance, by no means easily accounted for. It is, in the first place, absolutely essential to the existence of these animals that the element in immediate contact with the respiratory surfaces should be renewed as rapidly as it becomes deteriorated; or suffocation would inevitably be the speedy result of an inadequate supply of fresh and aërated water—to secure which, especially when the valves of the shell are closed, no adequate provision seems to exist. Secondly, it is natural to inquire, how is food conveyed into the mouth? for in an animal, itself fixed and motionless, and at the same time, as in the case of the creature we are now considering, quite deprived of any means of seizing prey, or even of protruding any part of its body beyond the margins of its abode in search of provision, it is not easy to imagine by what procedure a due supply of nutriment is secured. Wonderful, indeed, is the elaborate mechanism employed to effect the double purpose of renewing the respired fluid, and feeding the helpless inhabitant of these shells. Every filament of the branchial fringe, examined under a powerful microscope, is found to be covered with countless cilia in constant vibration, causing by their united efforts powerful and rapid currents, which, sweeping over the entire surface of the gills, hurry towards the mouth whatever floating animalcules or nutritious particles may be brought within the limits of their action, and thus bring streams of nutritive molecules to the very aperture through which they are conveyed into the stomach,—the lips and labial fringes acting as sentinels to admit or refuse entrance, as the matter supplied be of a wholesome or pernicious character. So energetic, indeed, is the ciliary movement over the entire extent of the branchial organs, that, if any portion of the gills be cut off with a pair of scissors, it immediately swims away, and continues to row itself in a given direction as long as the cilia upon its surface continue their mysterious movements.

(1293.) Our next investigations must be concerning the internal anatomy of the Conchiferous Mollusca. In the *Oyster*, the general disposition of the body resembles that of the *Pecten* described above; and the mouth, enclosed between two pairs of delicate lips, occupies a similar position at the termination of the branchial lamellæ. In this well-known mollusk the œsophagus is extremely short, so that the mouth appears to open at once into the stomachal cavity (fig. 248, *a*), which is imbedded in the substance of the liver (*d*),—the biliary secretion being poured into the stomach itself through several large orifices, represented in the figure. A very peculiar arrangement exists in the stomachs of many genera, the digestive cavity being prolonged in one direction, so as to form a lengthened cæcum, or blind sacculus, wherein is lodged a cartilaginous styliform body, the use of which is not easy to conjecture, although its office is no doubt connected in some way or other with the preparation of the food. The liver is proportionately of large dimensions, and is at once recognized by its greenish or, in some cases, dark chocolate colour; it is entirely separable into masses of secerning follicles loosely connected together by a delicate cellulosity. The intestine varies considerably in extent, and, as a necessary consequence, in the arrangement and number of its convolutions. In the *Oyster* it is comparatively short, bending twice upon itself, and winding around the stomach and adductor muscle (b, c, d, f); its termination (g) projecting between the folds of the mantle upon the opposite side of the body to that where the mouth is situated, and so disposed that excrementitious matter is cast out beyond the influence of the ciliary currents. In *Pecten* we have already noticed that it performs sundry gyrations through the visceral mass, as well as about the muscle that closes the shell (fig. 247, c, n, m); while in the Cockle-tribes it even penetrates the base of the foot and winds extensively through its muscular substance (fig. 253). In the greater number of the Conchifera, but not in the Oyster-tribe, there is a very remarkable circumstance connected with the course of the intestine, the object of which is involved in obscurity: the rectum, at some distance from its termination, passes right through the centre of the ventricle of the heart, its coats being tightly embraced by the muscular parietes of that viscus.

Fig. 248.



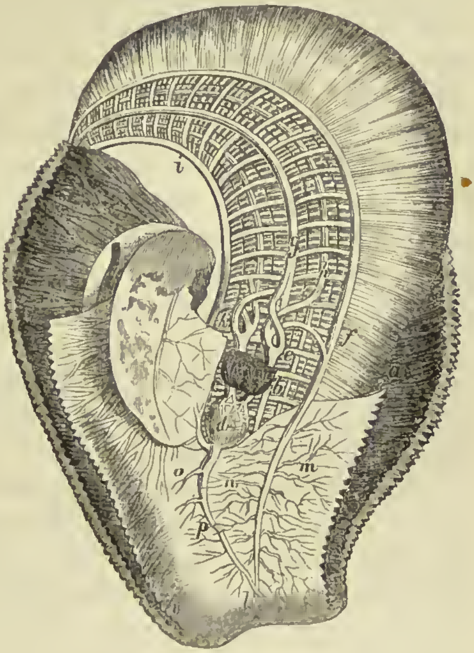
Alimentary canal of the Oyster (*Ostrea edulis*).

(1294.) The position of the branchiæ in the Ostracean family has been already described; it now remains therefore to notice their intimate structure, and the arrangement of the vessels connected with respiration and the circulation of the blood. The branchial fringes are.

of course, essentially vascular in their composition, being, in fact, made up of innumerable delicate parallel vessels enclosed in cellular tissue of extreme delicacy, and exposing a very extensive surface to the influence of the respired medium. The countless branchial canals through which the blood is thus distributed terminate in large vessels enclosed in the stems to which the fixed extremities of the vascular fringe are attached (fig. 249, *f*, *g*, *h*, *i*); these communicate extensively with each other, and, ultimately uniting in two principal trunks (*e*, *k*), pour the purified blood derived from the whole branchial apparatus into the auricle of the heart.

(1295.) The heart in the *Oyster* (fig. 248, *n*, *o*) is situated in a cavity between the folds of the intestine and the adductor muscle, in which position, from the dark-purple colour which it exhibits, it is at once distinguished. It consists, in the species we are more particularly describing, of two distinct chambers—an auricle and a ventricle. The auricular cavity (fig. 249, *b*), the walls of which are extremely thin, and composed of most delicate fasciculi of muscular fibres, receives the blood from the respiratory apparatus, and by its contraction transmits it through two intermediate canals (*c*) into the more muscular ventricle (*d*), whence it is propelled through the body by the ramifications of the arterial system (*n*, *o*, *p*).

Fig. 249.



Heart and respiratory system of the Oyster.

(1296.) The above description of the circulatory apparatus as it exists in the Oyster is applicable in all essential points to every family of Conchiferous Mollusca; but there are important modifications in the structure of the heart and arrangement of the blood-vessels, met with in different genera, which now demand our attention. Most generally, in consequence of the broad and dilated form of the animals, instead of a single auricle, such as the Oyster has, there are two auricular cavities, one appropriated to each pair of branchial lamellæ, and placed symmetrically on the two sides of an elongated fusiform ventricle, into which both the auricles empty themselves, till the course of the blood is similar to what we have described above.

(1297.) A still greater modification is found to exist in those species most remarkable for their breadth. In *Arca*, for example, there are not only two auricles, but two ventricles likewise, placed upon the opposite sides of the body; that is, there is a distinct heart appropriated to each pair of gills,—each receiving the blood from the branchiæ to which it belongs, and propelling it, through vessels common to both hearts, to all parts of the system.

(1298.) We must now, before entering upon the description of other families of Conchifera, examine the character of the locomotive apparatus with which those possessed of the power of moving about are furnished. The instrument employed for this purpose is a fleshy organ appended to the anterior part of the body, called the *foot*: but of this apparatus, for obvious reasons, no vestige is met with in the fixed and immoveable Oyster; and even in the Scallop we have seen only a rudiment of such an appendage. When largely developed, as in *Mactra* (figs. 250 & 251), the foot forms a very important part of the animal, and becomes useful for various and widely-different purposes. In structure it almost exactly resembles the tongue of a quadruped, being entirely made up of layers of muscles crossing each other at various angles—the external layers being circular or oblique in their disposition, while the internal strata are disposed longitudinally. In the Cockle-tribe (*Cardium*) this organ attains to a very great size; and on inspecting the figure given in a subsequent page, representing a dissection of the foot of *Cardium rusticum* (fig. 253), the complexity of its muscular structure will be at once evident, and the disposition of the several layers composing it more easily understood than from the most elaborate verbal description.

(1299.) Diverse are the uses to which the foot may be turned. It is generally used for burrowing in the sand or soft mud; and, by its constant and worm-like action, those species in which it is largely developed can bury themselves with facility, and make their way beneath the sand with a dexterity not a little remarkable. Perhaps the most efficient burrowers met with upon our own shores are the Razor-shells (*Solenidæ*), in which family the fleshy foot attains to enormous proportions; and the rapidity of their movements beneath the soil will be best appreciated by those who may have watched the manner in which the fishermen effect their capture.

(1300.) The *Solen* excavates for itself a very deep hole in the sand, boring its way by means of its *foot* to a depth of some feet, and remains concealed in this retreat, usually occupying a position within a few inches from the surface. The fisherman, armed with a slender iron rod furnished with a barbed head, resembling a harpoon, treads carefully backwards over the beach left bare by the retreating tide, and finds the holes in which *Solen* lodges by watching the little jet of water thrown out by the animal when, being alarmed by the shaking of the sand, it contracts its body. Guided by the orifice through which the water is thrown, he plunges his rod into the sand, and generally succeeds in piercing the animal with the barbed extremity, and dragging it from its concealment; but should he fail in his first attempt, he well knows that to try again would be unavailing, for the animal instantly works its way down to such a distance as to render pursuit hopeless.

(1301.) But, however efficient as a means of burrowing the foot may be, it can be turned to other purposes. The *Pholades*, for example, by some means, either of a mechanical or chemical nature, not as yet precisely determined, excavate the solid rocks, and form therein chambers in which they pass their lives. In such genera, the foot, which would be useless as a boring instrument, by being simply transformed into a broad and flat disk becomes a powerful sucker, whereby the *Pholas* fixes itself to the walls of its apartment in any convenient situation.

(1302.) In many of the Cockle-tribe we find the foot converted into an instrument of locomotion of a very singular description, enabling the *cardiaceous* Conchifera to leap by bounds we should scarcely expect animals so unwieldy to be capable of executing. For this purpose the end of the foot is bent, and placed firmly against the plane of support, in the position represented in fig. 252; when thus fixed, a sudden spring-like action of the muscles of the foot throws the cockle into the air, and, by a repetition of these exertions, the creature can skip about with surprising agility.

(1303.) But the most extraordinary office assigned to the foot in the class under consideration is the manufacture of horny threads, whereby, as by so many anchors, the Mollusca thus provided fix themselves securely to foreign bodies, and that so firmly, that extraordinary violence is requisite to wrench such animals from the place where they have fixed their cables. The marine Mussel is a well-known example of a *byssiferous* Mollusk; and from this species, therefore, we shall draw our description of the organs by which the tough filaments referred to are secreted.

(1304.) The foot in the *Mussel* is of small dimensions, being useless as an instrument of progression. By its inferior aspect it gives attachment to the horny threads of the *byssus*, which are individually about half an inch in length, or as long as the foot itself, by which, in fact, they are formed in a manner quite peculiar to certain families of Conchifera—no other animals presenting a secreting apparatus at all analogous, either in structure or office, to that with which these creatures are provided. The manner in which the manufacture of the byssus is accomplished is as follows:—A deep groove runs along the under surface of the foot, at the bottom of which thin horny filaments are formed by an exudation of a peculiar substance, that soon hardens and assumes the requisite tenacity and firmness. While still soft, the Mussel, by means of its foot, applies the extremity of the filament, which is dilated into a kind of little sucker, to the foreign substance whereunto it wishes to adhere, and fastens it securely. Having accomplished this, the foot is retracted; and the thread, of course, being drawn out of the furrow where it was secreted, is added to the bundle of byssus previously existing, all of which owed its origin to a similar process.

(1305.) Sometimes, instead of the numerous thin filaments met with in the Mussel, the byssus consists of a single, thick, horny stem; while in other cases, as, for example, in *Pinna*, the threads are so numerous, soft, and delicate, that they are not unfrequently spun like silk, and manufactured into gloves and other small articles of dress not unfrequently met with in the cabinets of conchologists.

(1306.) Taking a more general view of the Conchiferous Mollusca than we have hitherto done, we shall now proceed to consider the mechanism for opening and closing the valves of the shell in which they reside,—an operation effected in a very simple and elegant manner.

(1307.) The shells are connected posteriorly by means of a hinge, differently constructed in different species. In the Oyster we have an instance of the most simple kind of junction. In these Mollusca, a mass of elastic ligament, composed of perpendicular and parallel fibres, is interposed between the posterior edges of the shell, and so disposed that, by closing the shell, the ligamentous mass is forcibly compressed, while at the same time its resiliency is such that, immediately the compressing power is withdrawn, it expands, and thus forms a simple spring calculated to keep the valves apart and cause their separation to a greater or less extent.

(1308.) The antagonist to this elastic force is the *adductor muscle* (fig. 247, *c*), a fleshy mass of very great strength, the fibres of which pass directly from one valve to the opposite. The adductor muscle, although in this case single, consists of two portions of different texture (fig. 248, *l*, *m*); so that it would appear to be formed by two muscles closely approximated so as to compose a single powerful mass adapted to keep the valves in contact, with a force proportioned to its massive size. All those species having a single muscular mass, such as the Oyster and Pecten, have been grouped together by conchologists under the general name MONOMYARIA, while another and more numerous division, DIMYARIA, is characterized by having two adductor muscles, distinct and widely removed from each other. The Mussel-tribe and many others are examples of this arrangement, which is represented in subsequent figures.

(1309.) Simple as the structure of the hinge is in the Ostracea, in other Bivalves it frequently exhibits far greater complexity, and the opposed valves present prominent elevations and deep fossæ which lock into each other, and thus form a very secure articulation of great strength and solidity. In such cases the arrangement of the elastic ligament for opening the valves is slightly modified, being placed externally instead of within the shell, but its action in antagonizing the adductor muscles is still equally efficacious.

(1310.) We must, in the next place, solicit the attention of the reader to a very important subject connected with the economy of this class of Mollusks, viz. the growth and formation of their shells. Infinitely diversified are the forms presented by their testaceous valves, and equally various the colours which not unfrequently adorn their external surfaces. Some exhibit a beauty and delicacy of sculpture of a most exquisite character; others, covered with large spines, or festoons of calcareous plates, puzzle the beholder to comprehend how the growth of such parts, in the situations which they occupy, can be effected with so much regularity of arrangement. The shells themselves are permeated by no vessels, and as incapable of expansion by any internal power as the rocks to which they are not uncommonly attached; so that the young naturalist is necessarily at a loss to conceive either the mode of their formation, or the origin of all the gaudy tints and external decorations that render them the ornaments of our cabinets.

(1311.) The simple apparatus by means of which shells are constructed is the external membranous layer that invests the body of the mollusk—the mantle, as it has been termed; and, whatever the form of the shell, it owes its origin entirely to this delicate organ.

(1312.) In order to simplify as much as possible our description of the process whereby the shell is formed, it will be necessary to consider it under two points of view: first, as relates to the enlargement of the valves in length and breadth; and secondly, as regards their increase in thickness,—very different parts of the mantle being employed in the attainment of these two ends.

(1313.) It is the circumference, or thickened margin, of the mantle alone which provides for the increase of the shell in superficial extent. On examining this part (fig. 247, *h*; fig. 248, *e*), it is found to be of a glandular character, and moreover not unfrequently provided with a delicate and highly sensitive fringe of minute tentacula. Considered more attentively, it is seen to contain in its substance patches of different colours, corresponding both in tint and relative position with those that decorate the exterior of the shell.

(1314.) When the animal is engaged in increasing the dimensions of its abode, the margin of the mantle is protruded, and firmly adherent all round to the circumference of the valve with which it corresponds. Thus circumstanced, it secretes calcareous matter, and deposits it in a soft state upon the extreme edge of the shell, where the secretion hardens and becomes converted into a layer of solid testaceous substance. At intervals this process is repeated, and every newly-formed layer enlarges the diameter of the valve. The concentric strata thus deposited remain distinguishable externally; and thus the *lines of growth* marking the progressive increase of size may easily be traced (fig. 250).

(1315.) It appears that at certain times the deposition of calcareous substance from the fringed circumference of the mantle is much more abundant than at others: in this case ridges are formed at distinct intervals; or, if the border of the mantle at such periods shoots out beyond its usual position, broad plates of shell, or spines of different lengths, are secreted, which, remaining permanent, indicate, by the interspaces separating successively-deposited growths of this description, the periodical stimulus to increased action that caused their formation.

(1316.) Whatever thickness the shell may subsequently attain, the external surface is thus exclusively composed of layers deposited in succession by the margin of the mantle; and, seeing that this is the case, nothing is more easy than to understand how the colours seen upon the exterior of the shell are deposited, and assume that definite arrangement characteristic of the species. We have already said that the border of the mantle contains, in its substance, coloured spots; these, when minutely examined, are found to be of a glandular character, and to owe their peculiar colours to a pigment secreted by themselves. The pigment so furnished being therefore mixed up with the calcareous matter at the time of its deposition, coloured lines are formed upon the exterior of the shell wherever these glandular organs exist. If the deposition of colour from the glands be kept up without remission during the enlargement of the shell, the lines upon its surface are continuous and unbroken; but if the pigment be furnished only at intervals, spots or coloured patches of regular form, and gradually increasing in size with the growth of the mantle, recur in a longitudinal series wherever the paint-secreting glands are met with.

(1317.) The carbonate of lime (for such is the earth whereof the shells of bivalves are principally composed) is, at the moment of its deposition, imbedded in a viscid secretion that forms a kind of cement; and on dissolving the shell in a dilute acid, the animal material thus produced remains in the shape of a delicate cellulosity, in the interstices of which the chalky particles had been entangled. If the proportion of the above-mentioned secretion be abundant, it not unfrequently, by hardening on the exterior of the shell, constitutes what has been very inaptly termed its *epidermis*, representing a comparatively soft external skin of semicorneous texture. If exceedingly thick, the epidermic layer thus formed becomes loose and shaggy, giving the shell a hirsute appearance; but, both in its structure and origin, such pilose investment has no claim to be considered analogous to the hair of animals possessing an epidermis properly so called.

(1318.) While the margin of the mantle is thus the sole agent in enlarging the *circumference* of the shell, its growth in *thickness* is accomplished by a secretion of a kind of calcareous varnish, derived from the external surface of the mantle generally, which, being deposited layer by layer over the whole interior of the previously-existing shell, progressively adds to its weight and solidity. There is, moreover, a remarkable difference between the character of the material secreted by the marginal fringe, and that furnished by the general surface of the pallial membrane: the former we have found to be more or less coloured by glands appointed for the purpose, situated in the circumference of the mantle; but as these glands do not exist elsewhere, no colouring matter is ever mixed with the layers that increase the thickness of the shell; so that the latter always remain of a delicate white hue, and form the well-known iridescent material usually distinguished by the name of *nacre*, or *mother-of-pearl*.

(1319.) Local irritation of various kinds is found to stimulato the mantle to increased action, so as to cause the pearly matter to be secreted more abundantly at the part irritated. Thus there are various minute boring Annelidans that, in the exercise of their usual habits, perforate the shells of oysters, and penetrate even to the soft parts of their bodies. Stimulated by the presence of these intruders, the mantle beneath the place attacked secretes nacre in inordinate quantities to repair the injured portion of the shell, and prominent nuclei are soon formed, which, enlarging by the addition of continually-added layers of nacreous matter, become so many pearls adherent to the interior of the shelly valves.

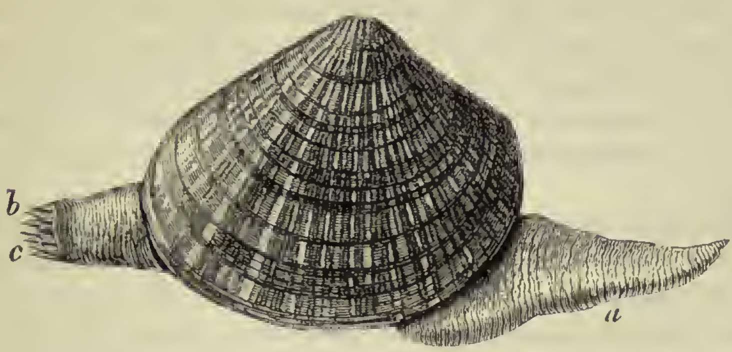
(1320.) Or pearls may owe their origin to another cause. It not unfrequently happens that sharp angular substances, such as grains of sand or fragments of stone, are conveyed between the valves, and become imbedded in the delicate tissue of the mantle. Thus irritated, the mantle throws out copiously the peculiar iridescent material which it secretes, and with it coats over the cause of annoyance, wrapping it in numerous concentric laminæ of nacre, and thus forming the detached and globular pearls so valuable in commerce.

(1321.) One other circumstance connected with the growth of bivalve shells requires explanation. From the earliest appearance of the shelly valves until the period when the included mollusks arrive at their mature size, the adductor muscle or muscles have been of necessity perpetually changing their position, advancing gradually forward as the enlargement of the shells was accomplished, so as to maintain in the adult precisely the same relative situations as they originally did in the young and as yet minute animal. Taking the Oyster for an example, it is quite obvious that the adductor muscle, which at first was connected with the thin and minute lamellæ forming the earliest shell, has, during the entire growth of the animal, become further removed from the hinge, and transferred from layer to layer as tho shell increased in thickness, till it has arrived at the position occupied by it in connexion with the last-formed stratum that lines tho interior of tho ponderous valves of the full-grown Oyster. The manner in which this progressive advance of the adductor muscle is effected is not at first easily accounted for, seeing that it is always fixed and firmly adherent at all points of its attachment. In order to understand the circumstances connected with its apparent removal, it is necessary to premise that a thin layer of the mantle itself is interposed between the extremities of the muscle and the inner surface of the shell, forming the bond of connexion between the two, and, like the rest of the pallial membrane, assisting in increasing the thickness of the shell by adding layers of nacre to its inner surface. Particle after particle is laid on by a kind of interstitial deposit between the mantle and the extremity of the adductor muscle, but so gradually, that the firm attachment between the muscle and the shell is not at all interfered with; and as the animal grows, the transference of the muscle from layer to layer is thus slowly and imperceptibly effected.

(1322.) We have as yet limited ourselves almost exclusively to a description of the simplest forms of Conchifera, namely those belonging to the *Ostracean* family, which, being generally incapable of locomotion, are deprived of a foot, and are recognizable by having the two lobes of the mantle unconnected with each other around their entire circumference. On turning our attention to the organization of the mantle in other families, we find that in them it no longer offers the same simple arrangement, but, the two lobes becoming gradually more and more completely united along their edges, the bodies of the mollusks are by degrees enclosed by the pallial membranes, and seem, as it were, sacculated. Moreover, sometimes the mantle is prolonged into membranous tubes of considerable length called *siphons*, through which the water is conveyed to the gills, and excrementitious matters expelled from the body. In the Mussels (*Mytilacea*) the edges of the mantle are partially joined, so as to present two apertures, through one of which the foot is protruded, while the other, the smaller of the two, gives issue to the excrement. A third family (*Chamacea*) has the circumference of the two divisions of the mantle still more intimately united, leaving three distinct fissures—one for the passage of the foot, another for the entrance of water to the branchiæ, and a third for the ejection of matter from the rectum. Of these, some are of gigantic dimensions, and fix themselves by a strong byssus. One species, indeed (*Tridacne gigas*), is so enormous in its size, that its shells alone not unfrequently weigh upwards of two hundred pounds, and hatchets are employed to chop its thick and tendinous cables from the rock to which it holds.

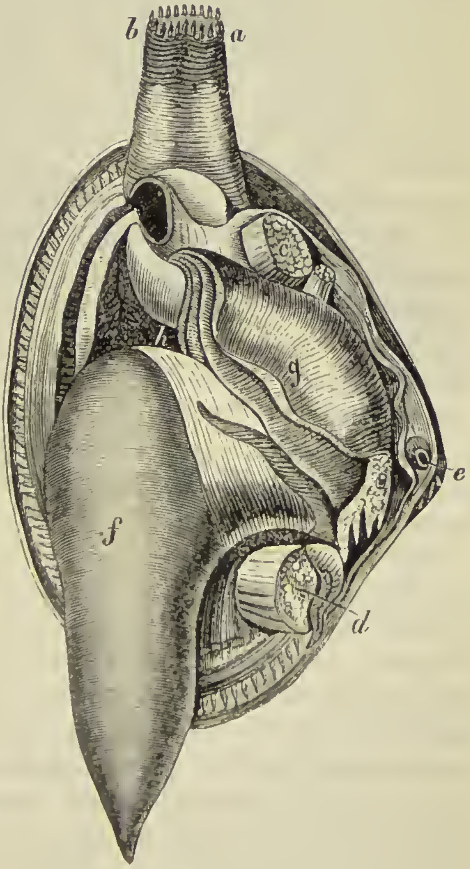
(1323.) The Cockle family (*Cardiacea*) is recognized by having the mantle open anteriorly, but prolonged at one extremity into two tubes, one of which admits the water for respiration, while the other discharges effete matter. In the Cockle (*Cardium*) the tubes are short, and scarcely reach beyond the shell (fig. 252, *a*); but in other genera, as, for example, *Mactra* (fig. 250, *b*, *c*), they are of such length, that, when extended, they protrude to a considerable distance. We at once perceive the use of the tubular arrangement of the mantle here referred to, when we reflect upon the already-mentioned habits of this extensive division of the Conchifera, and consider how, by means of their largely-developed foot, they burrow into the sand or mud of the shore. Had their mantle been open, like that of the Oyster, respiration would have been impossible under the circumstances in which they live; but, by the modification of structure thus provided, their tubes being prolonged to the mouth of the excavation wherein they reside, water is freely admitted to the branchiæ through one of the passages so formed, and excrement ejected through the other (fig. 251).

Fig. 250.



Mactra: *a*, foot; *b*, *c*, siphons formed by the mantle.

Fig. 251.



Mactra: *a*, *b*, siphons; *e*, hinge; *c*, *d*, adductor muscles; *f*, foot.

(1324.) Whoever watches these siphoniferous bivalves in a living state will readily appreciate the importance of the pallial prolongations forming this tubular apparatus; especially if minute floating particles are placed in the water wherein they are confined. It will then be perceived that powerful currents are perpetually rushing through the extremities of each siphon, caused by the rapid action of cilia placed within; and the streams thus produced not only form a provision for constantly changing the water in which the branchiæ (fig. 251, *g*) are immersed, but forcibly convey floating molecules to the aperture of the mouth, which is situated in the position indicated in the figure by the letter *h*, and thus supply abundance of nutritive materials that could, apparently, in animals so destitute of prehensile organs, have been procured by no other contrivance[*].

(1325.) The last family of this class includes those species which, like the *Pholas* and *Teredo*, bore in stone or wood, or, like the *Solen*, penetrate deeply into the sand. In such, the mantle is prolonged into terminal tubes of great length, and their shells remain always open at the extremities: these constitute the division to which Cuvier has applied the name "Enfermés," on account of the very complete union of the two sides of the mantle; and from such forms of CONCHIFERA the transition to the TUNICATA, described in the last chapter, is by no means difficult.

(1326.) In animals circumstanced as the CONCHIFERA, it would be vain to expect any high development of the nervous system, or senses of an elevated character; nevertheless a few small ganglia are perceptible in different parts, and nervous threads of extreme tenuity are seen to arise from them and to be distributed in various directions.

(1327.) One pair of ganglia, in the *Dimyaria*, is easily distinguished, occupying the ordinary position of the brain, namely above the œsophagus. Hence is derived a supply of nerves to the sensitive labial appendages, to the oral orifice, and other neighbouring parts. Two other ganglionic masses, of larger size than the brains properly so called, are placed near the posterior retractor muscle; and a fifth small ganglion, in those species provided with siphons, is found in the vicinity of the breathing-tube, the muscular walls of which receive nerves from this source.

(1328.) In the *Monomyaria* the nervous centres are still more feebly developed, and the posterior ganglia proportionately smaller than those found in species possessed of two adductor muscles.

(1329.) No organ of sense, other than those already noticed, is met with in any of the Conchifera, except in one remarkable instance. In the Scallops (*Pecten*) the edges of the mantle are studded with numerous pearl-like points, interspersed among the retractile tentacula placed around its circumference. These, which are represented in the figure of *Pecten* already given (fig. 247), are considered by Poli[†] to be so many distinct eyes thus singularly situated; and, from the circumstance of their being furnished with so many organs of vision, he applied the name of *Argus* to the mollusca possessing them. Should the brilliant specks in question be really *ocelli*, they certainly are placed in the only position where they can be efficient as instruments of sight, inasmuch as the margin of the mantle is, in such animals, the only portion of the body capable of being protruded beyond the boundaries of the shell to a sufficient distance to allow the creature to peep into the world around it.

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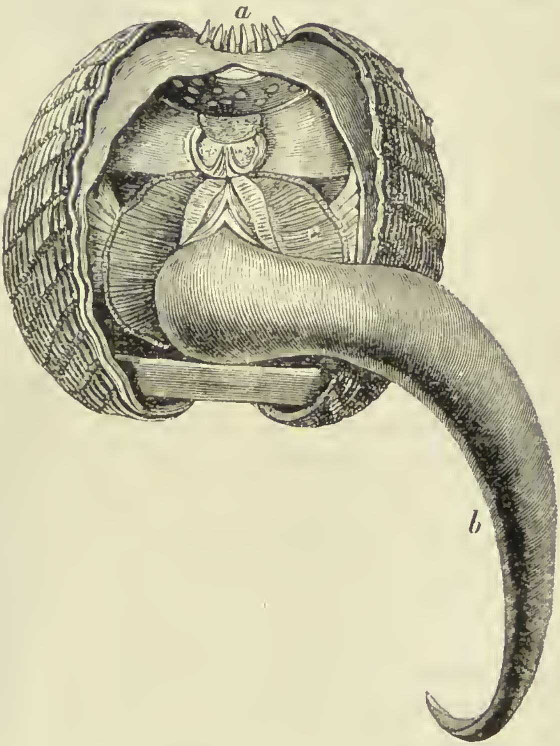
[*] The parts represented in the above figure (fig. 251) which are not particularly pointed out in the text are the anterior adductor muscle (*c*), the posterior adductor muscle (*d*), the elastic ligament of the hinge (*e*), and the largely-developed foot (*f*).

[†] Testacea utriusque Siciliæ, eorumque Historia et Anatome: 3 vols. fol.

(1330.) The elaborate researches of M. Siebold have demonstrated the existence of another sense in the Conchiferous Mollusca, namely that of hearing—or at least have pointed out the presence of an organ which from its structure seems to be appropriated to the reception of sonorous impressions. This remarkable apparatus is situated in the foot, and is thus described* by its discoverer as it occurs in *Cyclas cornea* :—"On compressing the extremity of the foot of this species between two plates of glass, we bring into view a large central nervous ganglion, and on each side of this there is a minute round reservoir, composed of an elastic, opake, and tenacious substance. In the centre of this is contained a perfectly transparent circular and flattened nucleus, which floats disconnected from the sides of the body that contains it, and has an oscillatory movement. This nucleus appears to consist of a crystalline salt."

Fig. 252.



Cardium: *a*, oral orifice; *b*, foot.

(1331.) The ovary is generally a wide glandular sacculus, occupying a considerable portion of the visceral mass. In the Oyster, when full of spawn, it is largely spread through the body; and if at such seasons its delicate walls are ruptured, countless ova of microscopic dimensions escape from the lacerated part. In *Pecten* the ovary is very conspicuous, from the brilliant colour of the eggs contained in its interior; it constitutes the greater part of the bulk of that prominent tongue-like organ which projects between the branchiæ (fig. 247, *f*): or in genera where the foot is very largely developed, as in *Cardium rusticum*, a great part of the base of that organ is hollowed out into a capacious cavity, enclosed by its muscular walls, wherein the delicate folds of the ovarium (fig. 253, *a*) are partially imbedded, together with a portion of the intestinal canal (*c*).

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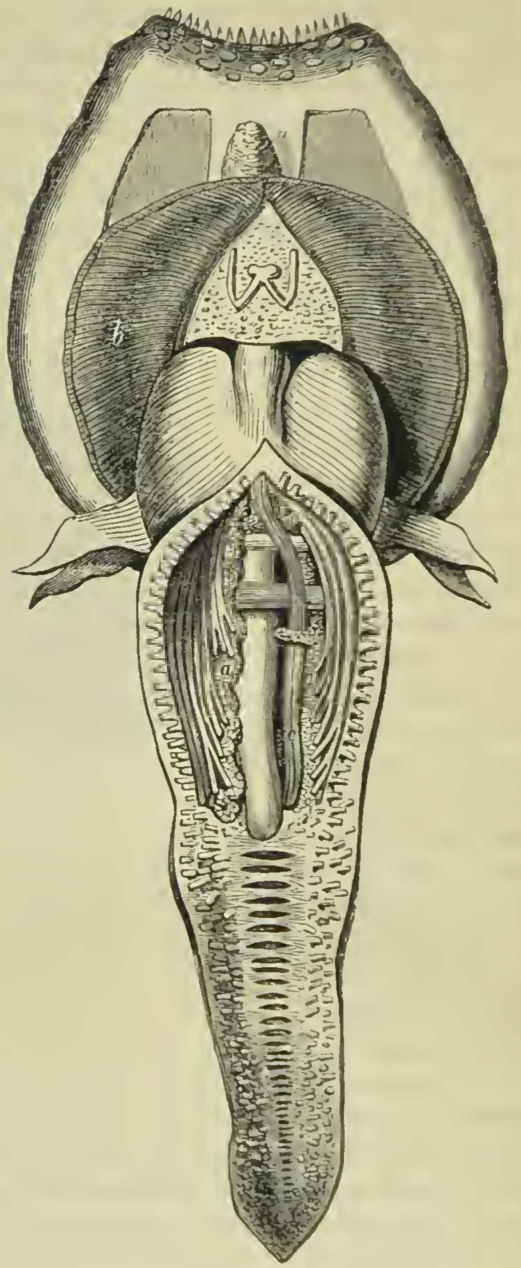
* Ann. des Sci. Nat. n. s. tom. ix.

Fig. 253.



Cardium rusticum.

(1332.) In almost all the Lamellibranchiate Acephala there is situated on each side of the body, near the insertion of the branchiæ, between the abdomen, the posterior muscle of the valves, the heart, and the liver, a gland, of a brown colour, which, from its discoverer, has received the name of the *organ or sac of Bojanus**, the nature of which has long been a puzzle to comparative anatomists. It seems to be intimately in relation with the reproductive apparatus, the excretory canals of which always open either into its interior or in its immediate vicinity. This organ is always readily recognizable. On separating the branchial lamellæ after placing the bivalve upon its back (that is to say, upon that part of its circumference which corresponds with the hinge), the student will observe on each side of the visceral mass an oblong body of variable tint, the shape of which depends more or less upon that of the animal.

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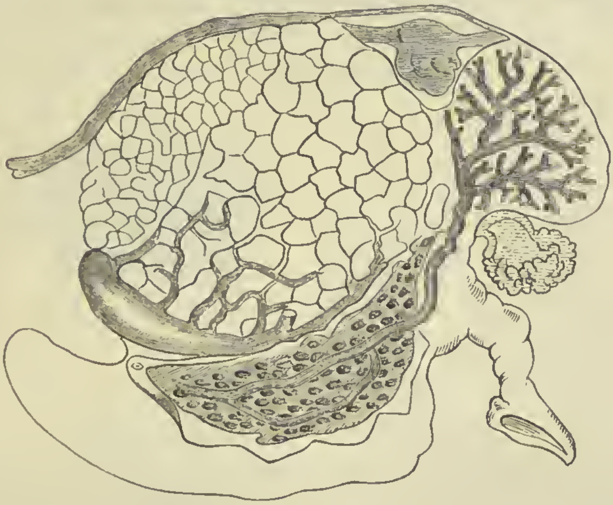
* "Mém. sur l'Organe de Bojanus," par Dr. H. Lacaze-Duthiers (Ann. des Sc. Nat. 1855).

(1333.) The structure of this gland is rather complicated, its interior being made up of numerous cavities communicating with each other. Its relations with the generative system present themselves under three aspects: sometimes the reproductive glands open immediately into its cavity; sometimes the two open externally by a common orifice; and sometimes two distinct orifices, more or less separated from each other, belong to each of the glands. The circulation through this remarkable viscus is of a venous character, and represents a portal system: hence it has been alternately regarded as a respiratory organ, a testicle, and a urinary apparatus; its real office, however, is still problematical.

Fig. 254.



Gland of Bojanus.

(1334.) On throwing injection into the genital orifices*, the sexual glands become tinged, and on examining fragments of such genital glands microscopically, the injected substance may be seen mixed with the ova and spermatozoa. These facts may be observed with special ease in the common Cockle (*Cardium edule*).

(1335.) Sometimes the ova may be seen actually laid by living females of *Modiolæ* and *Mytili*, one of the valves of whose shell has been removed, on irritation of the genital orifice; and in others, the ova or the spermatic fluid may be made to pass out of their orifices at the breeding season by pressing gently upon the foot. In *Spondylus gaderopus*, the genital orifice is situated in the sac of Bojanus, where the eggs may occasionally be seen issuing forth, in aspect like a thread of vermicelli, composed of reddish ova mixed with mucus.

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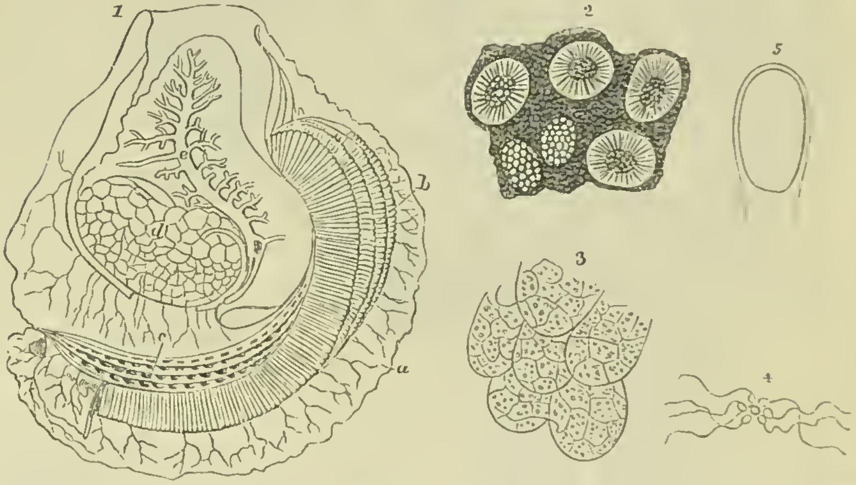
* *Vide* memoir by Dr. H. Lacaze-Duthiers, Ann. des Sci. Nat. 4e sér. t. ii.

(1336.) When we consider the position of the ovary in these bivalves, placed as it is in the substance of the body, and reflect upon the immense number of eggs to which they give birth (for thousands of ova are generated by every one of these prolific beings), we perceive that, without some special provision, the imprisoned animals would, when gravid, be seriously inconvenienced and exposed to continual danger, as the inordinate enlargement of the ovary would preclude the possibility of bringing the valves of the shell in contact with each other. In order to obviate the difficulty referred to, the ova are expelled from the ovarian nidus in an immature condition, and complete their growth in a situation where, being diffused over a larger surface, the shells may be closely approximated; and, moreover, the eggs and their contained offspring are by this contrivance freely exposed to the influence of the medium around, so as to allow a kind of respiration to be enjoyed by the unhatched young. The situation chosen is the branchial fringes, over which the imperfect spawn, or *spat*, as it is technically termed, is found widely spread towards the close of gestation, still retained beneath the shelter of the shell of the parent, and thus preserved from destruction, but at the same time, being in such a position freely washed by the ciliary currents, the respiration of the included embryo is adequately provided for.

Fig. 255.



1. Oyster (*Ostrea edulis*), showing the ramifications and excretory duct of the generative system. 2. Spermatic filaments. 3. Secerning culs de sac from an individual almost entirely male. 4. Spermatozoids, magnified. 5. Ovum enveloped in its capsule.

(1337.) In the large branchial laminæ of the freshwater Mussel, it is to be remarked that both pairs consist of an intertexture of vessels arranged in a rectangular lattice-work, and covered by a delicate membrane, whilst the two external are distinguished by a structure which merits particular description. Above each external lamina of the gills is a duct proceeding from the posterior part of the foot towards the anal tube, long ago described as an oviduct by Oken, and having, on its lower surface, a long row of openings placed transversely, and forming the entrances to the cells or compartments of the gills themselves. These compartments are all arranged vertically in the gill, and, separated from each other by partitions, they appear as though they originated from the mutual recession of the two membranous surfaces of the gill, which remain connected only by the vertically-disposed vessels that give rise to the septa; they serve for the reception of the ova, which, coming from the ovary placed within the foot, and not by any means in the gill itself, are, however, lodged there, and there receive their further development as in a uterus.

CHAPTER XXI.

BRACHIOPODA* (Cuvier).

Palliobranchiata† (Owen).

(1338.) The next class of Mollusca which presents itself for our consideration was named by Cuvier on account of the remarkable character of the organs by means of which the animals composing it procure the food destined for their support. These instruments consist of two long spiral arms placed on each side of the mouth, that in many species can be unrolled to a considerable length, and protruded to some distance in search of aliment. The above character, however, taken by itself, would scarcely warrant us in considering the creatures before us as forming a separate class of Mollusca; but when, in addition to this remarkable feature in their organization, we find that they possess a respiratory apparatus peculiar to themselves, and differ widely from all other bivalves in almost every part of their structure, we feel little hesitation in continuing to regard them as distinct, and devoting the present chapter to an investigation of their anatomy.

(1339.) The Brachiopoda inhabit bivalve shells, and for the most part are suspended by a fleshy tubular pedicle, resembling that of the Cirrhopods, to various submarine bodies. Such, at least, is the case in *Lingula* and *Terebratula*; but in the third genus belonging to this class, namely *Orbicula*, the pedicle is wanting, the lower valve of the shell being fixed immediately to the rock whereunto the animal is attached.

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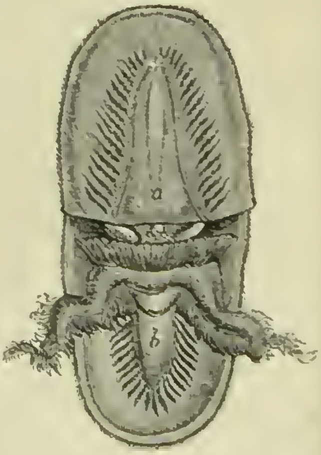
* *βραχίων*, an arm; *ποῦς, ποδὸς*, a foot.

† *pallium*, a mantle; *branchiæ*, gills. This name, originally proposed by M. de Blainville notwithstanding his belief that the spiral arms were the organs of respiration, has since been proved by the researches of Professor Owen to be strictly appropriate to the class.

(1340.) The shells of the Brachiopoda are formed upon two plans—one having the valves articulated, the other having them unarticulated*. Those with articulated valves (*Waldheimia*) have the hinge generally furnished with teeth and corresponding sockets, which so lock the valves together that their movements are very limited. In the unarticulated forms (*Lingula*) the valves do not move upon each other, for when open no part of their margins are in contact. The two divisions of the Brachiopods thus indicated will be found to be still more marked in their internal organization.

(1341.) The muscular system in the Brachiopods is very complicated and peculiar in its arrangement. Five or six pairs of muscles have been described in the Terebratulidæ, all of which have relation to the movements of the valves upon each other, or to their attachment to, or movements upon, the peduncle. Thus the muscles naturally divide themselves into two groups, the valvular, and those for adjusting the shell upon its peduncle. Of the former there are three pairs, which have been denominated respectively "adductors," "cardinals," and "accessory cardinals." Of the latter there are likewise three pairs, whichh ave been designated the "dorsal pedicle muscles," the "ventral pedicle muscles, and the "capsular muscles;" the capsular muscles are, however, generally blended into one.

Fig. 256.



Lingula, with the valves separated: *a*, *b*, the pallium or mantle. (After Cuvier.)

(1342.) On separating the testaceous valves, the body of the Brachiopod is found to be enclosed between two delicate membranes, which exactly line the shell; and to these membranes, as in the case of other mollusks, the name of *mantle* has by common consent been appropriated. The mantle itself is thin and semitransparent; but its margins are thickened, and fringed with delicate setæ.

(1343.) When the two lobes of the mantle are widely divaricated, as in *Lingula* (fig. 256), we perceive the prominent orifice of the mouth (*b*) placed deeply between them: on each side of the mouth are the two fleshy fringed arms, which in this case can be protruded to a distance out of the shell, and, as Cuvier† supposes, may act as oars, and thus enable the animal slightly to alter the position of its body; or else, as they are most probably delicate organs of touch, they may perform the office of highly sensitive tentacula.

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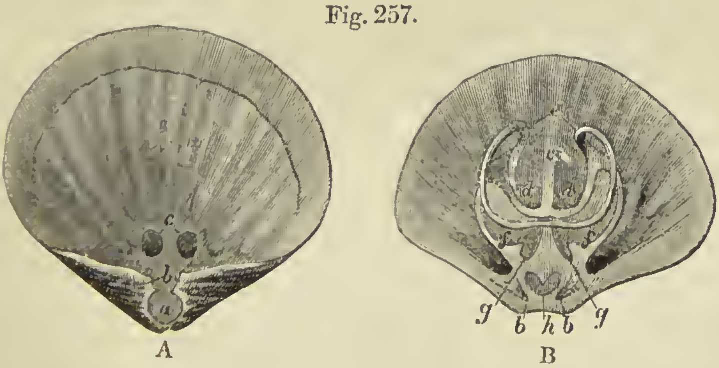
* "On the Organization of the Brachiopoda," by Albany Hancock, F.R.S. (Phil. Trans. 1858).

† "Mémoire sur l'Animal de la Lingule."

(1344.) In *Terebratula psittacea* the arms are enormously developed, fringed upon their outer margins, and quite free except at their origins: when completely contracted, they are disposed in six or seven spiral folds; and when unfolded, they extend beyond the shell twice its longitudinal diameter. The mechanism by which they are unfolded is described by Professor Owen* as being extremely simple and beautiful. The principal stem of each arm is hollow from one end to the other, and contains a fluid, which, being acted upon by the spirally-disposed muscles forming the parietes of the canal, is forcibly injected towards the extremity of the arm, and the organ is thus expanded and protruded outwards.

(1345.) In *Terebratula Chilensis*, on the contrary, the movements of the arms are extremely limited, and they can no longer be protruded from the shell as in the preceding species, being connected throughout their whole length with a peculiar complex testaceous apparatus attached to the internal surface of the imperforate valve of the shell (fig. 257, B), the arrangement and uses of which are thus described in the memoir above-mentioned:—The principal part of the internal framework alluded to consists of a slender flattened calcareous loop (*f f*), the extremities of which are attached to the lateral elevated ridges of the hinge: the crura of the loop diverge, but again approximate each other as they advance for a greater or less distance towards the opposite margin of the valve; the loop then suddenly turns towards the imperforate valve, and is bent back upon itself for a greater or less extent in different species. The loop, besides being fixed by its origins, or crura, is commonly attached to two processes (*d d*) going off at right angles from the sides, or formed by a bifurcation of the extremity of a central process (*c*), which is continued forwards from the hinge; but it is sometimes entirely free except at its origins. The arches of the loop are so slender,

Fig. 257.



Valves of *Terebratula Chilensis*, showing the internal framework. (After Owen.)

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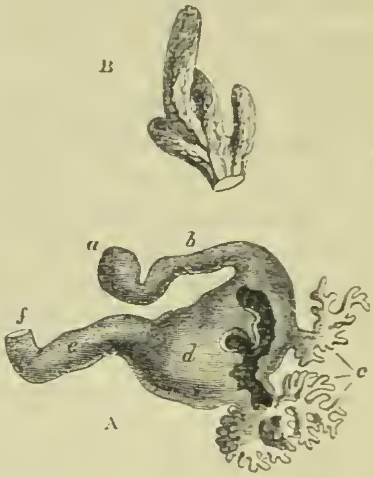
* Transactions of the Zoological Society, vol. i.

that, notwithstanding their calcareous nature, they possess a slight degree of elasticity, and yield a little to pressure. The interspace between the two folds of the calcareous loop is filled up by a strong but extensile membrane, which binds them together, and forms a protecting wall to the viscera; the space between the bifurcated processes in *T. Chilensis* is also similarly occupied by a strong aponeurosis. In this species the muscular stem of each arm is attached to the outer sides of the loop and the intervening membrane. They commence at the pointed processes at the origin of the loop, advance along the lower portion, turn round upon the upper one, are continued along it till they reach the transverse connecting bar, where they again advance forwards, and terminate by making a half-spiral twist in front of the mouth.

Fig. 258.



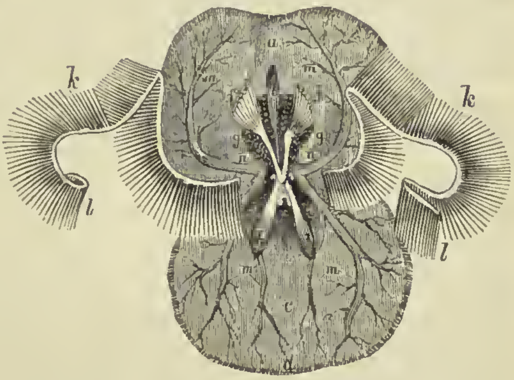
Digestive apparatus of *Terebratula*. A: *a*, *b*, *d*, *e*, *f*, the alimentary canal; *c*, the hepatic cæca. B: hepatic follicles, magnified.

(1346.) The most obvious function attributable to the tentacular organs of the animals composing this class is connected with the procurement of food; for, being utterly deprived of prehensile instruments, without some adequate contrivance these helpless creatures, imprisoned in their testaceous covering, and fixed immoveably in one locality, would be utterly unable to obtain the nourishment necessary for their support. The provision for this purpose is found in the arms, whether they be extensible or attached to calcareous loops; for these organs, being covered by cilia, produce powerful currents in the surrounding medium, which, being directed towards the mouth as to a focus, hurry into the oral aperture whatever nutritive particles may chance to be in the vicinity. The mouth itself is a simple orifice with prominent fleshy lips (fig. 256, *b*), but unprovided with any dental apparatus. The alimentary canal in *Lingula* is a long and convoluted tube, but without a perceptible stomachal dilatation; in *Terebratula*, however, there is a large oval stomach (fig. 258, A, *d*), into which numerous ducts derived from the hepatic follicles open by large orifices. The structure of the liver in these animals is displayed by Professor Owen in the memoir from which the annexed figures are taken; and the simplicity of its organization affords an interesting lesson to the physiologist. The hepatic organ (fig. 258, A, *c*) consists essentially of numerous secerning cæca (fig. 258. B), as yet easily separable from each other; over which the visceral blood-vessels ramify, and bring to the secreting sacculi the circulating fluid from which the bile is elaborated.

(1347.) The *Infusoria* appear to be the chief food of all the Brachiopods, perhaps the only food of the articulated species. In the latter, siliceous cases of the *Diatomaceæ* are almost always found, and sometimes in abundance. *Lingula,* however, appears to be a more general feeder, its intestine frequently containing a great variety of matter.

(1348.) The greatest peculiarity observable in the structure of the Brachiopoda is seen in the arrangement of the respiratory system; for these animals, instead of possessing proper branchial organs, as is the case with all other Mollusca, have the mantle itself converted into a respiratory surface, and traversed by the ramifications of large blood-vessels, which form an elaborate arborescence spreading through its texture, so that it is obviously well adapted to perform the office assigned to it, more especially as its circumference is thickly studded with vibratile cilia, disposed in such a manner that by their ceaseless movements they impel continued supplies of aërated water over the whole of this vascular membrane. The lobe of the mantle which lines the perforate valve of *Terebratula Chilensis* (fig. 259, *c*) contains four large longitudinal venous trunks or sinuses (*m m*), and two others of similar dimensions are seen in the opposite lobe (*a*). These sinuses take their origin by innumerable radicles from a circular canal of great delicacy which encompasses the entire circumference of the mantle (*d*).

Fig. 259.



Vascular system of *Terebratula Chilensis*: *a*, *c*, the mantle; *d*, circular canal encompassing the margin of the mantle; *f*, *g*, *h*, muscles of attachment; *m m m m*, large venous trunks in the mantle.

(1349.) A heart is present in all the Brachiopoda; and when in an expanded state, it is of considerable size. In the articulated species, it is appended to the middle line of the stomach, and projects freely into the perivisceral cavity, reaching down almost to the anterior margin of the oviducts. Its walls, when expanded, though rather thin, are firm, and do not collapse. They are composed of two layers, the inner of which is distinctly muscular, the fibres running in various directions, but principally radiating from centres; the outer layer is transparent and homogeneous. The interior is devoid of columnæ carneæ, and perfectly smooth. When this organ is in a contracted state, its size is very much reduced, the surface is slightly wrinkled, and the walls much thickened.

(1350.) This unilocular heart in *Waldheimia australis* receives a large blood-channel or vessel in front, which, running forward along the dorsal ridge of the stomach, within the membrane denominated mesentery, communicates on each side by several minute openings with the gastric *lacunæ*, which will be more particularly noticed hereafter. The anterior extremity of this channel passes down the dorsal surface of the œsophagus, and, dividing into two lateral trunks, opens at each side into a system of large lacunes placed around the alimentary tube. This channel is the afferent cardiac channel or branchio-systemic vein.

(1351.) A little behind the point where the heart receives this channel, two aortic vessels pass off laterally. The two orifices communicating with these vessels are guarded by sphincter valves, resulting apparently from the protrusion inwards of the lining membrane. From these vessels numerous branches are given off to supply the different viscera. The peripheral portion of the circulation is composed of an extensive system of lacunes or blood-channels, originally described by Professor Huxley, which, when the specimen is in good condition, are easily traceable, the channels or spaces being then, for the most part, filled with blood-corpuscles, which give to the lacunes an opake yellowish hue, rendering them as distinct and sharp as though they had been injected; and as the circular points of union between the layers of membrane forming their walls are transparent, and consequently liable to appear of a darkish tint, they show like spots on a light ground, not altogether unlike the markings upon a leopard's skin. In other lights, the whole has a beautiful lace-like delicacy. These lacunes occasionally assume a dendritic or branched character, particularly as they approach the margin of the mantle, where they become minute, and run almost parallel to each other, forming minute twigs, which pass on to the external circumference of the lobe.

(1352.) The inner lacunes, or those of the inner wall or floor of the great pallial sinuses, have a very different character; they resemble, however, the lacunes in the anterior wall of the body, with which they are in communication. They are in the form of numerous narrow channels, which, anastomosing at various points, compose a network of very long transverse meshes; thus most of the channels cross the direction of the sinuses, and run parallel to each other. Hence it would seem that the walls of the body and the laminæ of the pallial lobes present one great system of blood-channels or lacunes, the various parts of which freely communicate with each other, and surround all the viscera of the body.

(1353.) The blood-system of the brachial apparatus next claims attention. This is beautifully developed, and presents considerable variety in the plexuses of which it is composed. The walls of the great canal, the ridge supporting the cirri, the membranes that unite the upper and lower membranes of the loop, and that which connects the spirals, all have their systems of lacunes, which intercommunicate and form the brachial system. Let us now proceed to follow the course of the blood through this complicated vascular apparatus. It has been shown that the heart is a simple, unilocular, pyriform vesicle suspended from the dorsal aspect of the stomach, and projecting freely into the perivisceral chamber; that there is neither auricle nor pericardium, unless the membrane which closely invests it can be so called; that it is hardly more complex in structure than the pulsatile vessel of the Tunicata; nay, in *Lingula* it scarcely at all differs from the heart of those lowly-organized mollusks. This vesicle or heart propels the blood through four arterial trunks or channels to the reproductive organs and mantle, and probably also to the alimentary tube, and is apparently assisted by four or more pulsatile vesicles in connexion with those principal trunks. The blood thus conveyed by the genital and pallial arteries will escape by the lacunes in the membranes suspending the genitalia, into the plexus in the floor of the great pallial sinuses. Thence it will find its way into the outer lacunary system of the pallial lobes, and into that of the dorsal and ventral walls of the body, as well as into the lacunæ of the anterior parietes.

(1354.) Having saturated all these parts of the peripheral system, it will divide itself into two currents, one of which will set backwards in the direction of the membranous bands connecting the alimentary tube to the parietes, and will flow through their channels into the system of visceral lacunes, which encircle the alimentary canal, within its sheath, and which probably carry blood to the liver. This current will also supply the lacunes nourishing the muscles. The blood thus directed will reach the branchio-systemic vein, either by the great œsophageal lacunes, or through the foramina which penetrate the sides of the channel, as it runs along the dorsal ridge of the stomach:

(1355.) The other blood-current will set forward in the direction of the base of the arms, and some of it will pass into these organs through their general system of lacunæ; but the principal portion will be carried by the afferent brachial canal to the extensive plexus of lacunes in those parts, and will circulate in the walls of the great brachial canal. The blood will then be drawn up one side of the cirri, through the vessels (the afferent brachial arteries) originating in the great brachial plexus, and, returning down the other, will be poured into the efferent brachial canal, and thus reach the lateral efferent sinuses at the root of the œsophagus. Thence it will enter the great œsophageal lacunes, and, there meeting with the other current of returning blood from the visceral lacunæ, will be carried to the heart by the branchio-systemic vein along the dorsal aspect of the stomach. Thus it will be seen that the blood finds its way back to the heart in a mixed condition. That which is conveyed by the gastro-parietal and other channels will be imperfectly aërated, having only flowed through the pallial membranes, which must be looked upon but as accessory oxygenating agents. The arms undoubtedly perform the office of gills, and are true respiratory organs. The blood which circulates through them will consequently be returned in a perfectly aërated condition, to be mixed, however, with that in a less pure state from the visceral lacunes, before it enters the heart. This mixed state of the blood is not by any means peculiar to these animals; for it obtains in many of even the higher Mollusks.

(1356.) *Nervous system.*—As in all true Mollusks, the ganglionic centres are placed in connexion with a nervous collar surrounding the œsophagus. In *Waldheimia australis* the collar is situated at the commencement of the alimentary tube; and there are five nervous centres, three of which, on account of their superior size, may be assumed to be the principal œsophageal ganglia, from which nerves are given off to supply the pallial apparatus, the muscles, and the various viscera of the body.

(1357.) No special organs of sense have yet been observed; indeed, sight, hearing, or smell could be of little use to animals like the Brachiopods, deprived of locomotion, and firmly fixed during the whole period of their lives to one spot. Forbes and Hanley, in their 'British Mollusca,' regard as ocelli and otolitic capsules certain red spots, perceptible in some species at the bases of the setigerous follicles; but these Mr. Hancock thinks are nothing more than glandular matter in connexion with the growth of the setæ.

(1358.) The *Reproductive system* of the Brachiopoda has been minutely described by Mr. Albany Hancock in the memoir above quoted. In *Waldheimia australis* the generative organs consist of thick bands somewhat convoluted and ramified; they are of a full yellow colour, and are lodged in the trunks and main branches of the great pallial sinuses. There are four of these bands, two in each lobe: those in the dorsal lobe are single, and occupy the two outer or lateral sinuses, extending from behind the attachment of the occlusor muscles to within a short distance of the anterior margin of the mantle; their posterior extremities reach to the perivisceral chamber. The ventral pair extend as far forward as the dorsal, and are double, that is, each forms a loop, the free extremities of which pass into the outer and inner sinuses of the same side; the looped portions lie within the perivisceral chamber. These genital bands are attached to the inner lamina of the mantle throughout their whole extent by a membrane which, originating in this lamina, passes into a groove extending along the under surface of the genital band. The genital or pallial artery runs along the edge of this membrane, and has the reproductive organ developed around it. This is the most obvious disposition of the parts, as apparent on a general examination: but on a closer inspection, there can be but little doubt that these organs are in reality developed between the two membranes which compose the inner lamina of the mantle, and, bulging out the interior of these, become suspended, as it were, in the pallial sinus. Those in which ova are deficient are generally supposed to be the male secreting organ. The form, colour, and general appearance of these eggless bands do not differ, however, from those charged with ova, and have very much the character of undeveloped ovaries. The generative organs are very perceptibly composed of two elements—the yellow ovigerous substance, which forms the chief mass, and a red material, which is distributed over the surface of the organ. When the organ is in a low state of development, this red matter forms a narrow irregular cord, which runs along the sides of the band, and is occasionally spread over the surface in spots and blotches. When the ova are mature, this substance can still be traced as small specks on the surface and throughout the mass. From what will shortly be stated in regard to *Lingula*, it seems probable that this red matter may prove to be the testis.

(1359.) The minute structure of these organs has not been sufficiently examined; it may be stated, however, that the ova appear to be developed in cells, and that when the yellow mass which is deficient of eggs is broken up and placed under the microscope, it is found to be composed almost entirely of minute clear granules. The red substance is likewise made up of large irregular cells inclining to oval, very variable in size, and without any apparent nucleus.

(1360.) In *Lingula* the reproductive organs are withdrawn altogether from the mantle, and placed in the perivisceral cavity: they are very bulky, occupying a large portion of the chamber; they lie for the most part behind the liver, and surround the alimentary tube; they form four irregularly lobulated branched masses, two above and two below the tube; these pairs may be denominated the dorsal and ventral ovaries. When in a highly developed state, the lobes or branches insinuate themselves between and around the muscles, so that it is almost impossible to trace the relation of these organs to other parts; but when immature it is very easy to do so. The dorsal ovaries are then found to be suspended by the ilio-parietal bands, the ventral by the continuation of these bands along the pseudo-hearts or oviducts. In both cases the attachment is along the margin of the bands, between the two layers of which they would seem to be developed. In *Lingula* the red substance alluded to above forms a dendritic or branched organ, spread over the external surface of the ovarian masses. On examining a portion of this branched organ under the microscope, it is found to be composed of large irregular cells, somewhat elliptical in form, and closely resembling those of the red substance in connexion with the ovaries in *Waldheimia*. The cells, however, in *Lingula* appeared to present different stages of development, varying much in size and form, and some of them were filled with numerous delicate hair-like bodies resembling spermatozoa. From these facts it can scarcely be doubted that the dendritic organ is the testis, and that the fusiform cells are fully developed spermatophora containing spermatozoids. It would thus appear that *Lingula* is androgynous: and if the red matter in connexion with the generative organs in the articulated Brachiopods should prove to be the same as the dendritic organ in the former, then in them also the sexes are combined.

(1361.) Professor Owen supposed that the ova, when mature, escape by the dehiscence of the pallial membranes. So long as no passage was discovered leading externally from the perivisceral chamber, this could be the only possible conclusion, but can now be no longer maintained, for it has been ascertained that more than one such passage exists. The natural inference would therefore seem to be that the eggs will find their way through these passages, which may consequently be looked upon as oviducts.

(1362.) These curious organs were originally described by Cuvier as hearts, in his well-known memoir on *Lingula anatina*, and subsequently by Professor Owen on the Brachiopoda generally; they open, however, externally, and therefore can have nothing to do with the vascular system.

(1363.) In *Lingula* the oviducts are rather peculiar in form, though essentially the same as in the articulated Brachiopods. They are two in number, and lie to a great extent between the two layers of the ilio-parietal bands, stretching along the lateral walls of the perivisceral chamber from the front to behind the dorsal attachment of the adjustor muscles, and are so concealed by the viscera and muscles that very little of them can be seen until these parts are removed. The expanded portions open upwards and towards the lateral walls of the body, through the processes of the ilio-parietal bands, close to the side-walls of the chamber. They are of a yellowish colour, and terminate at the external surface in two small diagonal slits, one a short way on either side from the median line, a little below the mouth. The walls have a glandular appearance, the inside being velvety from the numerous minute villi which crowd the surface.

(1364.) From the nature of these organs, it seems probable that the ova on their passage outwards may receive some external covering. In two instances in which the ova were mature, Mr. Hancock found them in vast numbers strewed about the perivisceral chamber, and in one of the oviducts several had penetrated nearly to the external orifice.

CHAPTER XXII.

GASTEROPODA* (Cuvier).

(1365.) Extensively distributed over the surface of the land, or inhabiting the waters either fresh or salt, there exist a very numerous body of Mollusca, differing widely among themselves in construction and habits, but distinguished by a peculiar locomotive apparatus common to the entire class, by means of which they are able to fix themselves to plane surfaces, and to move from place to place by a slow and gliding motion. The *Slug*, the *Snail*, the *Limpet*, and the *Whelk* afford familiar examples of their general form and external appearance; but species of different kinds are so common in every situation, that it would be wasting the time of the reader to dwell at any considerable length upon their ordinary configuration and usual mode of progression.

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* γαστήρ, the belly; πούς, a foot.

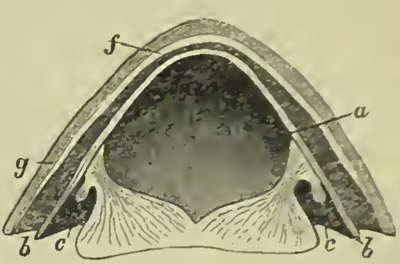
(1366.) Many families of Gasteropoda, as for example the NUDIBRANCHIATA (fig. 266), are absolutely deprived of any shelly defence, the investment of their bodies being entirely soft and contractile. In others, as the Slug (*Limax*), a thin calcareous plate is imbedded in the substance of their muscular covering. This little shell is contained in a cavity within the mantle, and is quite loose and unattached to the walls of the cell wherein it is lodged. The mode of its formation and growth is exceedingly simple, and from its very simplicity is well calculated to illustrate the formation of shells of more complex character. The floor of the cavity containing the calcareous plate is vascular, and secretes cretaceous particles mixed up with a viscid animal secretion. The material thus furnished in a semifluid state is applied like a layer of varnish to the lower surface of the shell already formed by the same process; and the added layer, soon hardening, increases the thickness of the original plate, while at the same time, as a necessary consequence of the progressive extension of the secreting membrane, which enlarges with the growth of the Slug, each successive lamina of shell is larger than that which preceded it. Thus the extension of the shell in diameter, as well as its increase in thickness, is easily explained. In these internal shells, however, there is no colouring matter; so that they are uniformly white, and present the same texture throughout.

(1367.) As external shells are generally painted upon their outer surface with colours of different kinds variously disposed, in such the process of growth is somewhat more complicated, and in every essential particular resembles that already described, whereby the shells of the CONCHIFERA are extended in size and thickness.

(1368.) We choose, as an illustration of the manner in which the external shells of univalves are manufactured, one of the least complex forms, as being best adapted to elucidate this part of our subject. The *Patella*, or common Limpet, is covered with a simple conical shell that extends over the whole of the dorsal surface of the mollusk. The testaceous shield that thus protects these animals is generally variegated externally with sundry markings of diverse colours, while within it is lined with a smooth and white nacre.

(1369.) On making a perpendicular section of one of these Gasteropods, the entire mechanism by which such shells are constructed and painted is at once rendered intelligible. The whole of the back of the animal covered by the shell is invested with a membranous *mantle*, like that of a conchiferous mollusk; but different parts of this mantle are appointed to different offices. The *extension* of the shell is entirely effected by the margin of the mantle (fig. 260, *b*), which is thick, vascular, and studded with glands appointed to secrete the colouring material that paints the exterior. This thickened fringe of the mantle is firmly glued to the circumference of the opening of the shelly cone: the earthy matter produced by it is added, layer by layer, to the edge of the shell; and wherever coloured glands are situated, this earthy secretion is coloured with a corresponding pigment: in this manner is the shell gradually enlarged, and every additional stratum of calcareous deposit is thus painted at the moment of its formation.

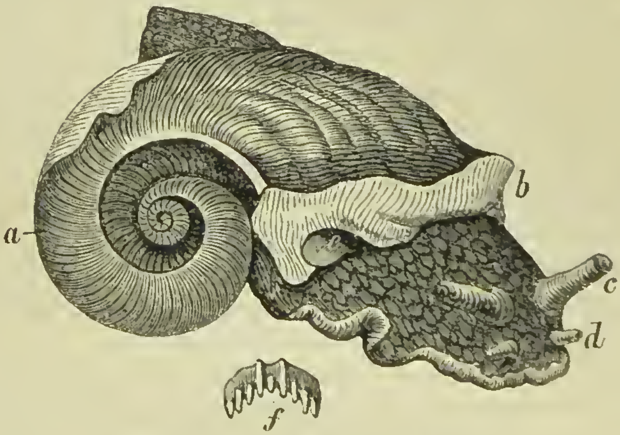
Fig. 260.



Section of *Patella*.

(1370.) The growth of the shell in *thickness* is a subsequent process. After the formation of the outer layer (*g*) by the *edge* of the mantle, the general surface of the pallial membrane (*a*) adds fresh laminæ of pearly matter (*f*) to the whole interior of the testaceous shield, and it is by the accumulation of such colourless depositions that the thickening of the entire fabric is provided for.

Fig. 261.

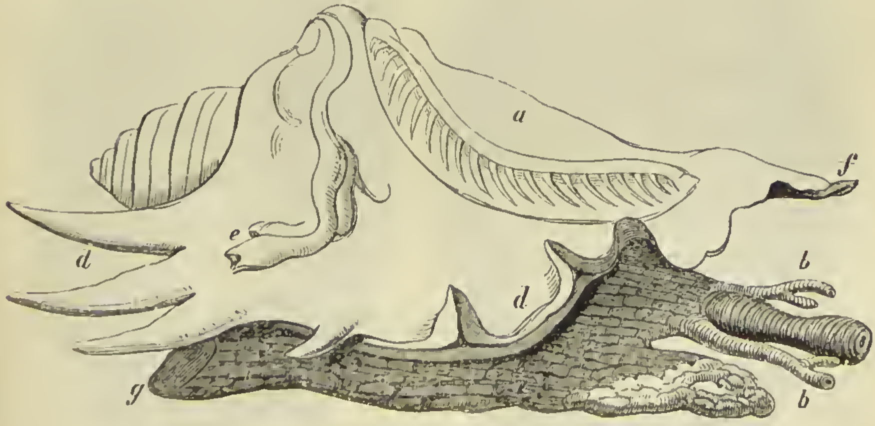


Helix pomatia, removed from its shell.

(1371.) When the manner in which the Limpet constructs its habitation is understood, the formation of a turbinated or spiral shell is explained with the utmost facility. On extracting a Snail from its abode, all that portion of its body which was covered by the shell is seen to be invested with a thin mantle (fig. 261, *a*) precisely analogous to that of the Limpet: from this pallial membrane the nacreous lining of the shell exudes. But around the aperture the mantle swells into a thick glandular collar (*b*), correspondent in function with the margin of the mantle in *Patella*, and in like manner provided with glands adapted to furnish colouring matter. From the collar, therefore, those layers are secreted by which the extension of the shell is accomplished; and as the deposit is in this case far more abundant in one direction than in another, the shell, as it expands, assumes more or less completely a spiral shape. Wherever glands for secreting coloured pigment exist, corresponding bands or coloured patches are produced as the layers of growth are formed, and the exterior of the shell is thus painted with the tints peculiar to the species.

(1372.) In many marine Gasteropods, spines and various external processes are found projecting from the outer surface of the shell, the production of which depends upon the shape of the margin of the mantle. Let the reader imagine one of these ornamented shells to be transparent, so as to permit the contained animal to be delineated *in situ*, as in the annexed sketch of *Pterocera* (fig. 262); and the collar, which forms the layers of growth, will be found to exhibit fringges or processes precisely resembling those upon the shell itself. But it is only at intervals that, as the growth of the mollusk proceeds, these pallial appendages encase themselves in a calcareous covering, every such interval being distinctly indicated upon the exterior of the shell by the spaces between the successive rows of spinous projections that mark the terminations of so many distinct periods in its formation; so that the number of ridges or rows of spines is, of course, correspondent with the age of the creature within.

Fig. 262.

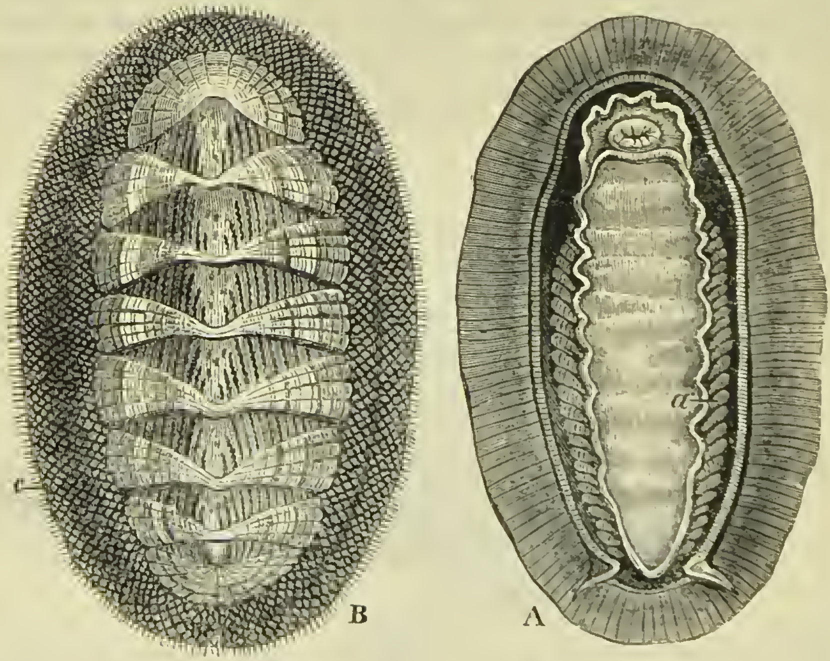


Animal of *Pterocera* in situ.

(1373.) Several of the Pectinibranchiate genera are provided with a very complete defence against the assaults of foes that might attack them while they are concealed in their habitations and, in such a posture, necessarily helpless and incapable of resistance. The provision for their protection is sufficiently simple: attached to the posterior extremity of the body, which is the part last drawn into its abode, is a broad horny or calcareous plate (fig. 262, g), called the *operculum*; this is of variable dimensions in different species, but always accurately corresponding in shape with the contour of the mouth of the shell. By this elegant contrivance a door is closely fitted to the aperture of its retreat whenever the mollusk retracts itself within its citadel, and, thus defended, it may safely defy external violence of any ordinary description.

(1374.) A most remarkable exception to the usual univalve condition of the shells in the Gasteropoda is observable in one solitary genus belonging to the Cyclobranchiate order. In *Chiton* (fig. 263) we find, instead of a turbinated or shield-like covering formed of one piece, a kind of armour composed of several distinct plates, arranged in a longitudinal series along the centre of the back, and overlapping each other like the tiles of a house.

Fig. 263.



Chiton: A, ventral; B, dorsal aspect.

(1375.) In these curious animals the whole back is invested with a dense leathery mantle of an oval form, and considerably more extensive than the cavity containing the viscera. Where not covered by the calcareous laminæ, the exterior of the mantle forms a broad edge variously sculptured in different species: but along its central part the shelly plates, generally eight in number, are partially imbedded in its substance; being, no doubt, secreted by the surface whereunto they are attached. These mollusks, notwithstanding the singularity of their covering, which almost reminds us of the armour of many Articulata, in their internal anatomy conform exactly to the type of structure common to the Gasteropod orders, and offer no peculiarities of organization worthy of special notice.

(1376.) Feeble and languid as are the sluggish movements of these creatures, they nevertheless present to the eye of the anatomist a type of organization considerably superior to any that we have had an opportunity of considering in such forms of the Heterogangliata as have been described in the preceding chapters. From the superiority of their mode of progression, it is evident that they are adapted to enjoy a less limited intercourse with external objects than even the most highly gifted of the burrowing Conchifera; and accordingly we find in them a nervous system exhibiting a more complete development, senses of a higher character, and, in the organization of their internal viscera, a complexity of parts such as has not heretofore fallen under our notice —every indication, in fact, that they are animals of a higher grade and more elaborate structure. The Gasteropoda, for instance, exhibit a distinct head, in which is lodged a supra-œsophageal ganglion of large proportionate size; and upon the head are found retractile instruments of sensation of peculiar structure, and not unfrequently perfectly-formed organs of vision.

(1377.) Let us, however, select one species for particular description; and after having become acquainted with the details of its anatomy, we shall be better prepared to examine such modifications of the various organs as are found in other orders destined to exist under different circumstances.

(1378.) The common Snails (*Helix*) are well known as far as relates to their external appearance; and, insignificant as they might be thought by those unacquainted with their habits, they not unfrequently become formidable pests to the horticulturist, from the ravages caused by their voracity. On examining a Snail more attentively, we find its body partially enclosed in a thick muscular envelope composed of transverse and longitudinal fibres, which, being unsupported by any skeleton, allows the shape of the animal to vary at pleasure, as it is shortened or elongated by the contractions of the muscles composing it. The foot, or ventral disk, is equally composed of an interlacement of muscular fibres, and not only forms an extensive sucker, but, by the successive action of various portions of its substance, a slow and gliding progressive motion is produced.

(1379.) From the head of the Snail when its body is expanded, as when in the act of seeking food, four tentacula are protruded (fig. 261, *c*, *d*), which, besides being exquisitely sensitive organs of touch, carry, at the extremities of the superior pair, two minute but perfect eyes. When the creature is at rest, the tentacula as well as the eyes are retracted into the visceral cavity, by a mechanism hereafter to be noticed. A large proportion of the viscera is enclosed in a turbinated calcareous shell, of sufficient capacity to allow the whole body of the animal to be withdrawn from observation and lodged in its interior.

(1380.) The mouth is situated upon the under part of the head, and, when widely opened, exhibits a cutting instrument of singular contrivance. Attached to the upper part of the muscular cavity that contains the oral apparatus there is a broad horny plate, the lower edge of which is free, very sharp, and slightly curved, forming, in fact, a knife (fig. 261, *f*), admirably adapted to divide the leaves and soft parts of vegetables when they are pressed by the action of the lips against its cutting edge.

(1381.) The floor of the mouth is provided with a small cartilaginous tongue, covered with delicate transverse striæ, and so disposed that by its movements it is well calculated to assist in propelling the food into the œsophagus.

(1382.) The œsophagus (fig. 264, *e'*) is continued from the muscular cavity (*c'*) that encloses the dental plate, and soon dilates into a wide stomachal receptacle (*v*, *r*), the posterior portion of which, when *in situ*, is imbedded among the viscera contained in the shell; but in the figure all these parts are unfolded and separated from each other. At the termination of the stomach, biliary vessels (*c*) are inserted, and the intestine commences,—the latter being a simple tube (*a*, *e*), intervolved among the masses of the liver, nearly of equal diameter throughout, and presenting internally neither valves nor any other remarkable appearance. Externally the intestine is intimately connected with the lobes of the liver, among which it lies imbedded, by means of a delicate cellulosity and vascular twigs passing from one to the other. The anal aperture (*o*), when undisturbed by dissection, is placed upon the right side of the neck, in the immediate vicinity of the orifice (fig. 261, *e*) that leads into the respiratory cavity.

(1383.) Two sets of auxiliary glands are subservient to digestion, the *salivary* and the *hepatic*, both of which are of considerable size.

(1384.) The salivary glands are semitransparent, and of a whitish colour; they form two irregular broad ribands, which extend along the sides of the stomach (fig. 264, *v*), spreading out so as to embrace a considerable portion of its extent, and they are occasionally joined together by intercommunicating processes. Two ducts, one derived from each gland, run along the sides of the œsophagus, and open into that canal close to the mouth.

(1385.) The liver is of large proportionate dimensions, and is made up of four lobes (fig. 264, *b*, *d*) of a dark-brown colour, and composed of an infinite number of minute lobules, every one of which produces a biliary vessel; and these, joining continually with each other, form four large hepatic ducts, one proper to every lobe of the liver. The four hepatic ducts ultimately unite into one great central vessel (*c*), that opens into the alimentary canal in the immediate vicinity of the pyloric extremity of the stomach.

(1386.) The genus of Gasteropoda to which the *Snail* belongs is composed of air-breathing animals; and we must accordingly expect to find these mollusca provided with a respiratory system specially adapted to the mode of life to which they are destined. The mechanism adopted is as follows:—A capacious chamber, of a somewhat triangular form, is found placed beneath the dorsal surface of the body, and separated from the visceral cavity by a broad muscular septum forming its floor. Into this chamber a wide orifice (fig. 261, *e*), placed upon the right side of the body near the margin of the shell, allows the atmospheric air to enter. The roof of the respiratory cavity is covered with a most intricate arborescence of blood-vessels (rudely sketched in fig. 264, *k*), in which the blood is freely exposed to the air therein contained; while the muscular floor, performing alternate movements analogous to those of the human diaphragm, continually draws in and expels the air, so as to ensure its constant renewal. The manner in which respiration is effected, and the general disposition of the circulatory apparatus, is therefore briefly this:—The blood derived from all parts of the body is brought to the respiratory chamber by large veins provided for the purpose; arrived there, it is dispersed through the countless ramifications of delicate vessels spread over the entire roof of the breathing cavity, and thus becomes exposed to the purifying influence of oxygen. The renovated blood is then re-collected by the large pulmonary vein (*k*); and being conveyed to the heart, which is composed of a single auricle (*h*) that communicates with a strong ventricular cavity (*g*), it is propelled through the entire arterial system derived from the aorta (*f*).

(1387.) The whole of that part of the body of the Snail which is not permanently covered by the shell is defended by a thick skin, the surface of which is irregularly furrowed, and continually moistened by a viscid secretion that exudes from glands apparently imbedded in the substance of the integument; and the tenacious slime so furnished, if the creature be irritated, is poured forth in astonishing abundance.

(1388.) Nevertheless, besides the slimy material thus copiously supplied by the tegumentary glands, there is in the interior of the animal a special apparatus apparently destined to furnish a viscid fluid of a similar character. The gland alluded to, called by Cuvier*, *par excellence*, "the secerning organ of the viscosity," is in the Snail a triangular viscus (fig. 264, *i*) placed in immediate contiguity with the pericardium.

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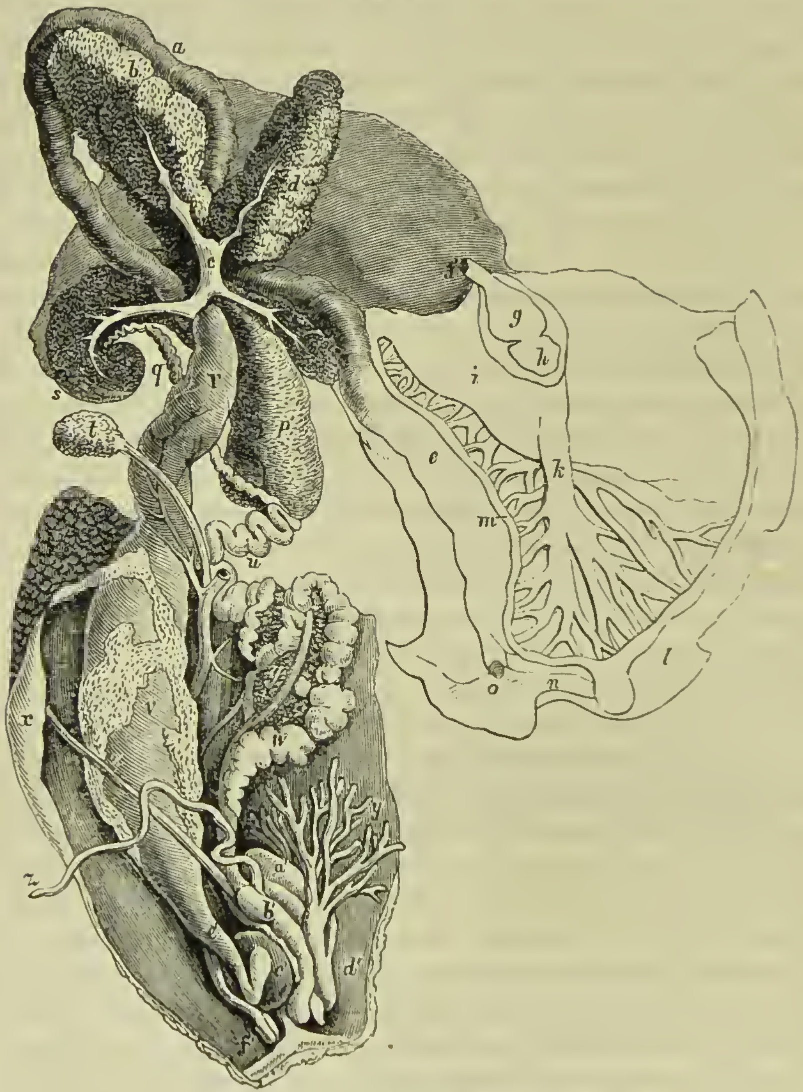
[*] Histoire des Mollusques—Mémoire sur la Limace et le Colimaçon.

On opening it, it is found to be filled with an infinite number of very thin laminæ that adhere to the walls of its cavity by one of their edges, and become joined to each other as if by communicating branches. The excretory duct of this slime-secretor, which, we may observe, is found to exist in many other genera of Gasteropods, accompanies the rectum to its termination, where it opens externally in the immediate vicinity of the orifice leading into the respiratory chamber.

Fig. 264.



Anatomy of the Snail (*Helix pomatia*).

(1389.) An organ, named by Swammerdam the "sacculus calcareus," has recently been supposed by Mr. Jacobson to perform the office of a kidney. "Chemical analysis of the matter secreted by this viscus has led him to discover in it uric acid, ammonia, or calcareous salt, and water. He was unable to discover any trace of uric acid in any other part of the animal; and as, in the superior animals, the kidneys are the only organs which, in a state of health, secrete uric acid, and as the calcareous sac of the Snails has many other anatomical relations with the kidneys, Mr. Jacobson concludes that this sac represents the kidneys, and must be so considered in all the Mollusca which are provided with it*."

(1390.) Before we enter upon a description of the somewhat complex generative system of a *Snail*, it will be proper to advert to one or two remarkable circumstances connected with the procreation of these singular animals. We must first premise that every individual is hermaphrodite, and moreover presents a kind of hermaphroditism of the most perfect and complete description, possessing elaborately-constructed male and female organs, which are distinct and separate from each other; but, nevertheless, the cooperation of two individuals is essential to the mutual impregnation of both. The manner in which they copulate is not a little curious, their union being accompanied by preparatory blandishments of a very extraordinary kind, that to a spectator would seem rather like a combat between mortal foes than the tender advances of two lovers. After sundry caresses between the parties, during which they exhibit an animation quite foreign to them at other times, one of the snails unfolds from the right side of its neck, where the generative orifice is situated, a wide sacculus, which, by becoming everted, displays a sharp dagger-like spiculum or *dart* attached to its walls. Having bared this singular weapon, it endeavours, if possible, to strike it into some exposed part of the body of its paramour, who, on the other hand, uses every precaution to avoid the blow, by speedily retreating into its shell. But, at length having received the love-inspiring wound, the smitten snail prepares to retaliate, and in turn uses every effort to puncture its assailant in a similar manner. The darts are generally broken off in this encounter, and either fall to the ground, or else remain fixed in the wounds they have inflicted. After these preparatory stimulations, the snails proceed to more effective advances. The *sac of the dart* is withdrawn into the body, and another sacculus is by a like process protruded from the common generative aperture. Upon the last-named organ two orifices are seen, one of which leads to the female generative system, while from the other a long and whip-like penis is slowly unfolded, being gradually everted like the finger of a glove, until it attains the length of an inch or more; and then each of the two snails, by inserting its penis into the female aperture of the other, impregnates its partner, and is itself impregnated at the same time. Such is the peculiar manner in which the amours of snails are conducted. Let us now examine the internal viscera connected with the process.

(1391.) The *sac of the dart* first requires our attention. This viscus, when uninverted (for it must be turned inside out in order to expose the weapon within it), is a thick muscular bag (fig. 264, *a'*); and on opening it, it is found to contain the dart, attached to a nipple-like protuberance at the bottom of the sac. The dart itself is four-sided; and as it grows by the constant addition of calcareous particles deposited at its base from the surface of the vascular protuberance to which it is fixed, so, if broken off, it is speedily reproduced in a similar manner.

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* Edinb. Journ. of Nat. and Geogr. Science, iii. p. 325.

(1392.) The male part of the generative system is composed of a *testicle*, *vas deferens*, and the whip-like *penis* above described.

(1393.) The *testicle* is considered by Cuvier* to consist of two distinct portions: one, a soft whitish oval mass (fig. 264, *p*); while the other is elongated, thin, and granular (*y*), being imbedded among the convolutions of the oviduct (*w*). The *vas deferens* forms the excretory duct of both these portions, and terminates in the side of the penis, its orifice becoming, of course, external when that organ is protruded by evolution. The intromittent organ itself, as seen when lodged within the body of the snail, consists of two parts, a muscular bag which forms its body (*b'*), and a long whip-like portion (*z*); the latter is hollow, but not perforated. The reader will now have little difficulty in understanding how this remarkable apparatus is protruded. The generative sac, common to both the male and female organs, first becomes inverted; the body of the penis (*b'*) then undergoes inversion in a similar manner, so that the orifice of the vas deferens appears externally; and lastly, the long appendage to the penis (*z*), being likewise turned inside out by the action of the muscles that compose its walls, completes this strangely-constructed instrument. Its subsequent retraction into the visceral cavity is effected partly by the assistance of a special retractor muscle, which acts upon the body of the penis, but principally by the same contractility that accomplished its evolution.

(1394.) The female system next demands our notice; and this will be found to present for our investigation an *ovary* and lengthy *oviduct*, to which are appended certain auxiliary organs, namely the *spermatheca* and the *multifid vesicles*.

(1395.) The ovary (fig. 264, *s*) is found situated in the inmost recesses of the shell, and partially imbedded in the substance of one of the lobes of the liver. From the ovary a long oviduct (*q*) is derived, which is at first thin and slender, but, soon becoming wider and more capacious (*u*), it gradually expands into an extremely convoluted intestiniform viscus, to which the name of *uterus* has been improperly given, and ultimately terminates in a canal derived from the spermatheca, to be described hereafter. It is during their passage through this enormous oviduct that the eggs attain their full growth preparatory to their expulsion from the body.

(1396.) Another viscus, called by Cuvier simply "*the bladder*," is, from the constancy of its occurrence, evidently an organ of importance; and there seems to be little room to doubt that it is intended to be a receptacle for the seminal fluid, analogous in function to the copulatory pouches we have already met with in Insects and some Crustacea. The reservoir in question, which we have called the *spermatheca* (fig. 264, *t*), is in the Snail placed above the stomach; and the canal derived from it accompanies the sacculated oviduct, which it ultimately joins near its termination, in such a manner that the ova must pass the orifice of its duct as they are expelled from the body. It must nevertheless be confessed that the office here assigned to the "bladder" is rather probable than positively established; for in the Slug, so nearly allied to the Snail in its general organization, the excretory duct of this organ opens into the common generative sac by an aperture distinct from that which leads into the oviduct, although even here the two are closely approximated. Cuvier suggests that perhaps it may furnish some material useful in forming an envelope for the ova; but experiments are still wanting upon this subject.

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* *Loc. cit.*

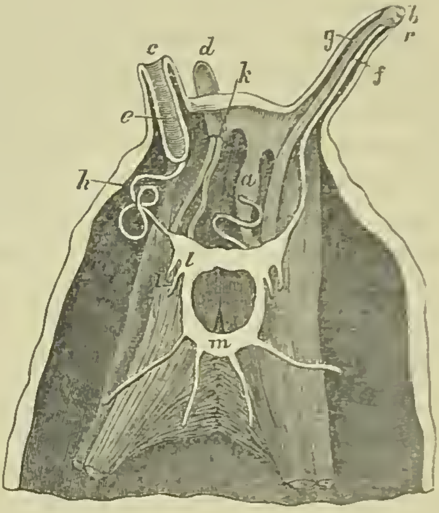
(1397.) There is still another set of organs connected with the canal by which the eggs escape from the oviduct of the Snail; and these, although peculiar to the genus we are examining, no doubt furnish a secretion of importance to their economy. They are called the *multifid vesicles* (fig. 264, *y*), and are composed of a series of branched cæca derived from two excretory ducts, by which a milky fluid, secreted by the cæca, is poured into the egg-passage prior to its termination.

(1398.) Although it will be convenient to speak in more general terms concerning the nervous system of the Gasteropoda than the examination of a particular species would permit, we deem it necessary, before closing our description of the Snail, to describe with some minuteness the senses possessed by these terrestrial mollusks, and more especially the extraordinary mechanism provided for withdrawing the most important instruments of sensation into the interior of the body when they are not in actual employment.

(1399.) The only senses that we can expect to meet with in animals deprived of either an external or internal skeleton are those of taste, smell, vision, and touch.

(1400.) The sense of taste, judging from the structure of their tongue, must be extremely obtuse; and although these creatures are evidently possessed of smell, it is not easy to point out where their olfactory apparatus is placed. The eyes, however, are now found to present a perfection of structure correspondent with the enlarged brain, and occupy a singular position, being situated at the extremities of the two superior tentacula appended to the head; while the inferior pair, adapted, as it would seem, more exclusively to the perception of tactile impressions, are deprived of visual organs. Both the upper and lower tentacula are retractile, and can be completely inverted, so as to be withdrawn into the interior of the body. To effect the inversion by which this end is attained, the plan represented in the accompanying figure is had recourse to. Each tentacle is a hollow flexible cylinder, the walls of which are muscular, and composed of circular fibres. When partially retracted, as in the tentacle marked (*c*) in the figure (fig. 265), the extremity of the organ is drawn inwards, and two cylinders are thus formed, one within the other: if the outer cylinder is elongated, as in protruding the tentacle, it is at the expense of the inner one; and, on the contrary, the inner cylinder, when the organ is retracted, is lengthened as the other becomes shorter. To evert the tentacle the contraction of the circular muscles that form its walls is sufficient, as they can gradually unroll the whole by squeezing out, as it were, the inner portion; but to effect its inversion a special retractor muscle is required. This muscle (*g*) arises from the general muscular mass composing the foot and retractile apparatus provided for drawing the snail into its shell: the long slip of muscular fibres so derived, accompanied by the optic nerve (*f*), traverses the interior of the cylindrical tentacle quite to its extremity, where it is attached, and thus, as the reader will easily conceive, is quite competent to cause its inversion. The lower feeler (*d*) is represented in the figure as partly retracted by the action of its appropriate muscle (*k*); while the corresponding one (*a*), being completely turned inside out, is fully withdrawn and securely packed among the viscera.

Fig. 265.



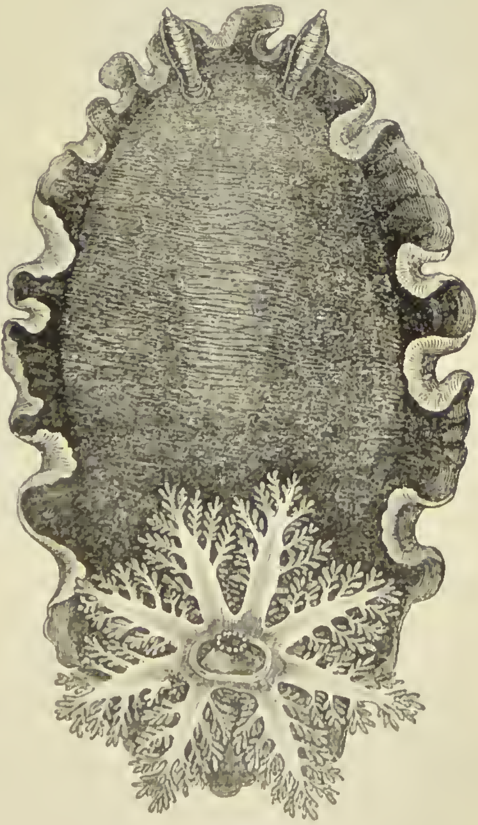
Structure of the tentacles of the Snail.

(1401.) One circumstance connected with the contrivance above described cannot but excite attention; and this is, the peculiar arrangement of the tentacular nerves, whereby they are adapted to changes of position so extensive: the optic nerve (*f*), for example, must not be stretched even when the eye-bearing tentacula are protruded to the uttermost; and in order to provide for this, when the feelers are not extended, the nerves become thrown into close folds (*h*), and lodged within the cavity of the body.

(1402.) From the above somewhat lengthened account of the anatomy of the Snail, the reader will at least have been able to become acquainted with the general features of an organization which is more or less common to all the members of the extensive class under consideration. We must now, however, enter upon a more enlarged survey of the GASTEROPODA, and divide them into such groups as will facilitate our further investigations concerning their structure and habits. The most convenient character by which the different orders composing the class are distinguished has been found to be derived from the nature and arrangement of the respiratory apparatus, which of course varies both in construction and position, according to the circumstances under which particular tribes or families are destined to exist.

(1403.) We have already found that terrestrial species, such as the Snail, breathe air, which is alternately drawn into and expelled from a cavity lined with a vascular network; and these, from the resemblance between such a mode of breathing and that of animals possessed of proper lungs, have been formed into an order distinguished by the name of PULMOBRANCHIATA. Nevertheless all the pulmobranchiate Gasteropoda are not terrestrial; our fresh waters abound with various species that respire air by a similar contrivance, and are consequently obliged, in order to breathe, to come continually to the surface of the shallow pools wherein they are found. The *Planorbis* and *Limnæus* are examples of this mode of respiration, and are met with in every ditch, where they voraciously devour the subaquatic vegetables upon which they feed.

Fig. 266.



Doris.

(1404.) It is at once evident that in marine Gasteropods another mode of aërating the blood must be resorted to, and branchiæ, of some description or other, substituted for a pulmonary cavity.

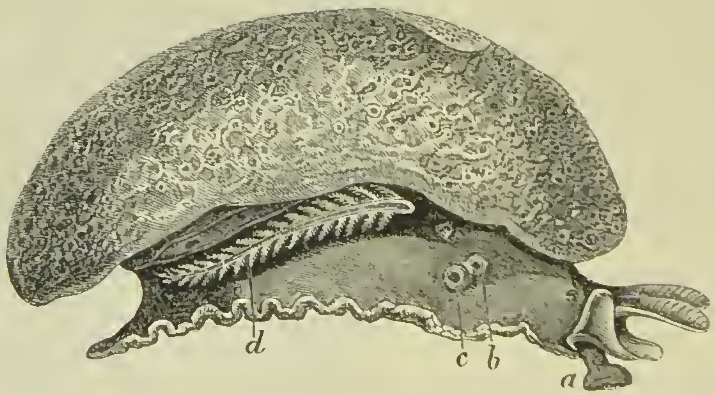
(1405.) The branchiæ given for this purpose are variously constructed—sometimes appearing as extensively branched and arborescent appendages to the skin, or else they form broad and thin lamellæ attached to the exterior of the body; but more frequently the respiratory apparatus consists of vascular filaments arranged in a pectinated manner along a central stem. Whatever their form, however, their office is the same, namely to present a sufficient surface to the surrounding medium, in order adequately to expose the blood that circulates abundantly through them to the influence of oxygen.

(1406.) It is from the position and arrangement of the branchial organs that the branchiferous Gasteropoda have been classified by zoologists. Thus, in the second order, called from this circumstance Nudibranchiata, they are naked, and placed upon some part of the back; sometimes, as in *Tritonia*, extending along its entire length; but in others, as for example in *Doris* (fig. 266), they are confined to its posterior part, and form a circle around the anal orifice, of exquisite beauty, and not inaptly comparable to a flower in appearance and disposition.

(1407.) In the Inferobranchiata the branchiæ resemble two long rows of leaflets, placed on the two sides of the body, under a projecting edge formed by the mantle.

(1408.) The Tectibranchiata have respiratory organs upon one side of the body only, and concealed by a flap derived from the mantle. Such, for instance, is the case with *Pleurobranchus* and *Aplysia*, in the former of which the elegant branchial fringe is situated in a deep sulcus between the edge of the mantle and the prominent margin of the foot (fig. 267, *d*).

Fig. 267.

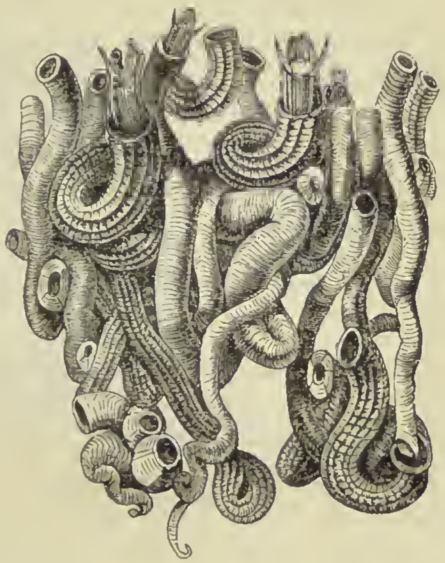


Pleurobranchus.

(1409.) But by far the most numerous order of the marine Gasteropoda (Pectinibranchiata), which, in fact, includes all the inhabitants of spiral univalve sea-shells, have their branchiæ placed internally in a capacious cavity, into which the water is freely admitted (fig. 262, *a*). This cavity is situated in the last or widest turn of the shell, and communicates with the exterior of the body by a very wide slit, to which in some genera a long siphon (fig. 262, *f*), formed by a fold of the mantle or general covering of the animal, conducts the respired fluid. The branchiæ themselves, as the name of the order indicates, are pectinated, and form a single, double, or triple series of gills suspended from the roof of the branchial chamber, answering the same intention as the pulmonary network of the Snail, but deriving their supply of air from the water in which they are perpetually immersed. In the figure referred to, representing a species of *Pterocera,* the position of the branchial chamber is seen through the shell and mantle, which the reader must suppose to be transparent; and the branchial organ (*a*), in this case single, is likewise represented *in situ,* suspended from the roof of the cavity that contains it.

(1410.) In fig. 275 the roof of the respiratory cavity (*x*) has been reflected, and the three rows of branchial fringes (*n*) suspended therefrom are well seen.

Fig. 268.



Vermetus.

(1411.) A sixth order of Gasteropods has been formed by Cuvier under the name of Tubulibranchiata, remarkable from the shape of their shells, which are long and irregular tubes, usually fixed to foreign bodies, but still they have the earliest-formed portion twisted into a few spiral curves. To this order belongs *Vermetus* (fig. 268), the shells of which, agglomerated into masses, might be taken for those of certain *Serpulæ.* As locomotion is here out of the question, owing to the immoveable condition of the habitations of such genera, the foot would seem at first to be altogether deficient, but upon close inspection it is found to be converted into a fleshy organ that bends forward and projects beyond the head, where its extremity expands into a disk furnished with a small operculum; so that, when the animal retires into its abode, a lid is formed adapted to close the aperture, and thus prevent intrusion and annoyance from without. Nevertheless even in these the branchiæ are pectiniform, forming a single row attached to the roof of a branchial chamber.

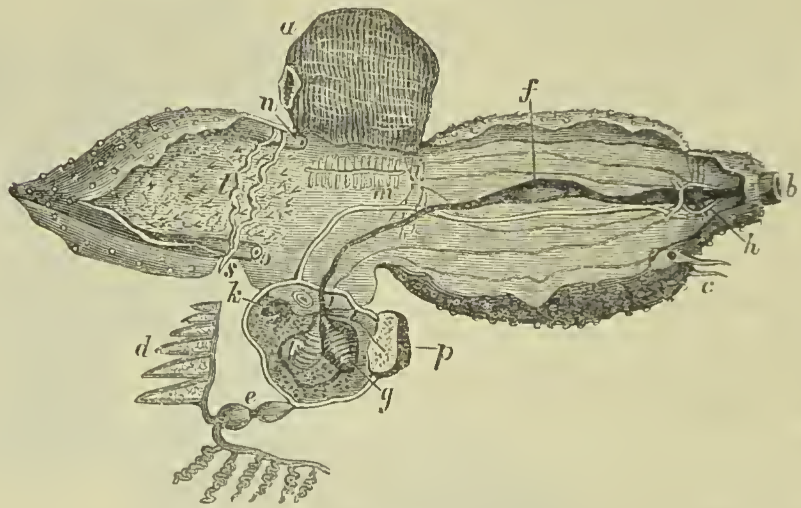
(1412.) The Scutibranchiata likewise have pectinated gills disposed in a special cavity; but their shells are very wide, and scarcely ever turbinated—a circumstance which, combined with other features of their economy, renders it convenient to consider them as forming an order by themselves.

(1413.) An eighth division of this extensive class takes the name of

Cyclobranchiata, because the branchiæ form a fringe around the body of the animal, between the edge of the body and the foot (fig. 260, *c*; fig. 263, *a*).

(1414.) Lastly, a distinct order has been established to embrace certain families in which the foot is so much compressed as to constitute a vertical muscular lamella, that presents merely a remnant of the ventral sucker so characteristic of the entire class, and which can only be serviceable in performing the office of a fin used in swimming; hence these mollusks have been called Heteropoda. Their branchiæ are placed upon the back (fig. 269, *d*), and resemble small detached tufts. The form of these heteropod Gasteropoda the reader will gather from an inspection of the accompanying figure, representing a species of *Pterotrachea*; but the details connected with their anatomy, therein delineated, will be explained hereafter.

Fig. 269.



Pterotrachea.

(1415.) It would be useless to weary the student by describing the course of the blood-vessels in all the orders we have just enumerated: their distribution necessarily varies with the changes observable in the position of the branchiæ; still, whatever the situation of the respiratory organs, the general course of the circulation is the same, and essentially similar to what has been already described in the Snail: one or two examples will therefore answer our purpose. In the *Pectinibranchiata*, as for instance in *Buccinum* (fig. 275), the heart (*r*, *s*), enveloped in a distinct pericardium, is placed at the posterior extremity of the branchial chamber, and consists, as in all the Gasteropoda, of two cavities—a thin membranous auricle, and a more muscular and powerful ventricle. It receives the blood from the organs of respiration by a large branchial vein (fig. 275, *q*), that communicates with the auricle (*s*). The contraction of the auricle forces the circulating fluid into the ventricle (*v*), which in turn drives it into the aortic or arterial system of vessels. The aorta, in the case before us, divides into two principal trunks, of which one (*m*) is directed forwards to supply the foot and anterior part of the body, while the other (*t*) winds among the mass of viscera contained in the shell, to which it distributes its ramifications. The blood thus dispersed through the system is taken up by the commencements of the veins, to be reconveyed to the branchiæ, there to begin again the circuit we have described.

(1416.) When the branchiæ are external, and largely distributed over the surface of the body, as for instance in *Tritonia*, the purified blood is brought from the branchiæ to the heart by capacious veins which run beneath each branchial fringe and collect it from the numerous respiratory tufts; or if, as in *Doris* (fig. 266), the branchiæ encircle the anus, a large circular vein placed at the base of the branchial apparatus receives the blood and pours it into the auricle. In all cases, however, the course of the blood is essentially the same, and the heart is systemic.

(1417.) In *Aplysia*, one of the tectibranchiate Gasteropods, the branchiæ (fig. 270, *a*, *b*) consist of delicate lamellæ minutely subdivided; and the vessel (*c*) which brings the blood derived from all parts of the body to be distributed over the extensive surface thus formed, presents a structure of no ordinary interest to the physiologist*. At some distance before it arrives at the respiratory organs it divides into two main branches; and the coats of each vessel so formed appear to be made up of transverse and oblique muscular bands that cross each other in all directions, so as to leave between them very perceptible apertures, through which injections of any kind readily escape into the abdominal cavity, and, of course, fluids derived from the abdomen as easily penetrate into the interior of the veins. At some points, indeed, these veins seem absolutely confounded with the visceral cavity,—a few muscular bands widely separated from each other, and not at all interrupting a free communication, being alone interposed. The result of Cuvier's anxious researches concerning this remarkable feature in the organization of these Mollusca led him to the following important conclusions, which are no doubt extensively applicable to the GASTEROPODA generally:—1. That in *Aplysia* there are no other vessels appointed to convey the blood to the branchiæ than the two above described. 2. That all the veins of the body terminate in these two canals. Now, as their communication with the abdominal cavity is evident and palpable, whether we call them *venæ cavæ*, or cavities analogous to a right ventricle, or *branchial arteries*,—for it is manifest that they fulfil the functions of these three organs,—the inevitable conclusion is, that fluids poured into the abdominal cavity can become directly mixed with the mass of the blood and thus conveyed to the branchiæ, and that the veins perform the office of absorbent vessels.

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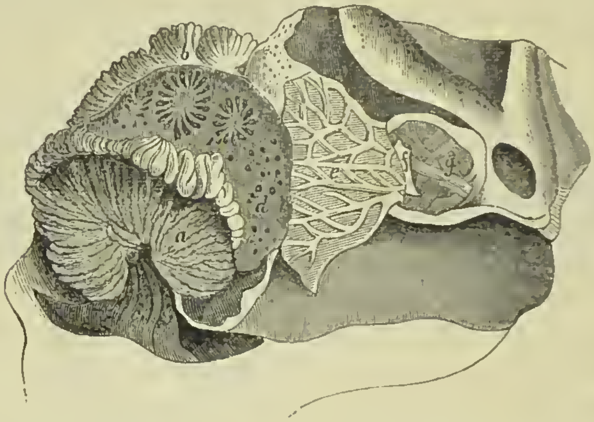
* Cuvier, Mémoire sur le Genre Aplysia.

(1418.) This extensive communication is undoubtedly a first step towards the establishment of that, still more complete, which nature has established in Insects, where, as we have seen, there are not even distinct vessels of any kind appointed for taking up the nutritive fluid. From these facts Cuvier concludes that no proper absorbent system exists in the Mollusca, still less in animals inferior to them in the scale of creation.

(1419.) The vein appointed to convey the renovated blood from the branchiæ to the heart, when slit open (fig. 270, *d*), exhibits the orifices of the smaller vessels derived from the respiratory laminæ arranged in circles. The auricle of the heart is made up of reticulated fibres (*e*); and when laid open it is seen to be separated from the more muscular ventricle (*g*) by a valve (*f*), whereby any retrograde movement of the blood is prevented.

Fig. 270.



Vena cava of *Aplysia* laid open.

(1420.) In *Aplysia*, the arterial blood, having been distributed throughout the body by means of the heart and aortic vessels, is received into a capillary system, which forms a rich network composed of minute vessels, the walls of which are perfectly distinct; but these capillaries are found not to be continuous with any system of recurrent vessels, but gradually resolve themselves into little lacunæ formed amongst the interstices which occur between the bands of cellular membrane and the fibres of various tissues. These vacuoles communicate in their turn with larger lacunæ, situated beneath the common integuments, or occupying the interspaces between the muscular fasciculi of the foot of the mantle, and of other parts of the body. The result of this arrangement is the formation of a vast system of venous cavities, dispersed throughout the abdominal parietes. In the foot and in the lobes of the mantle these lacunæ are very dilatable, and afford space for a considerable accumulation of fluid; in the dorsal region, on the contrary, they are small, and more densely congregated. It is this structure which constitutes the aquiferous system of Delle Chiaje; but it has no communication with the exterior of the body. The membrane, which imperfectly lines the abdominal cavity, separates this structure from the visceral chamber, but does not cut off the communication that exists between them ; on the contrary, the peritoneal tunic is itself of a spongy texture, and is perforated with numerous apertures, whereby a free passage is established between the subcutaneous lacunæ and the interior of the abdomen. In this way it happens that, when a coloured fluid is injected into the visceral cavity, the whole lacunary system becomes filled; and on throwing injections, even of coarse materials, into the muscular interstices of the foot or mantle, they are seen at once to diffuse themselves through the abdominal cavity.

(1421.) From the above and similar facts, Milne-Edwards has satisfactorily established the following important conclusions :—

1st. That no complete vascular system exists in any of the Mollusca.

2nd. That throughout a greater or less extent of the circulatory circle veins are entirely wanting, their functions being performed through the medium of lacunæ, or by the great cavities of the body.

3rd. That frequently the veins are wanting altogether, and that in such cases the blood distributed through the body by the arterial system can only return to the respiratory surface by the intervention of the interstitial lacunæ above described.

(1422.) Professor Huxley, in a letter addressed to Professor Milne-Edwards*, relative to the circulation of the blood, expresses himself very decidedly upon this important point in the anatomy of the Mollusca. In *Firola*, one of the Heteropod division, he observes that, owing to the perfect transparency of the body of this mollusk whilst alive, nothing is more easy than to observe the circulation of the blood throughout its entire course. In this creature *no veins whatever are observable.* The globules of the blood may be seen to issue in crowds from the open termination of the arteries of the foot, through the substance of which they immediately become diffused, and may likewise be observed to pass from the mass of the mouth, in which the aorta terminates, directly into the peri-intestinal cavity, in which they may be seen to return gently, frequently stopping in their course towards the heart. Occasionally some of them may be traced directly into the auricle, passing through the interspaces between the network of muscular fibres composing its walls†, in the meshes of which they may sometimes be observed to stop for a short period. When the animal begins to grow weak, and the circulation becomes enfeebled, it is even possible to follow with the eye any given globule during its passage through the peri-intestinal cavity, and through the heart into the aorta.

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* Ann. des Sci. Nat. 1850.

† In *Firola*, Professor Huxley assures us, the walls of the auricle of the heart are composed of a kind of lacework made up of striated and ramified muscular fibres, between which large open spaces are observable.

(1423.) In studying the anatomy of *Haliotis*, Milne-Edwards* observed that, although injections thrown into the heart were easily made to fill the general arterial system, so as to exhibit the arteries supplied to the liver, to the stomach, and internal viscera generally, and also to render visible even the capillary vessels, in the head he invariably found the injection extravasated so as to fill a great cavity, in which were lodged the brain, the salivary glands, the pharynx, and all the muscles belonging to the oral apparatus. At first it was supposed that this extensive extravasation was caused by some rupture of the vascular parietes; but after many unsuccessful attempts it was at last discovered that, on attempting to follow the course of the aorta into the head, it was impossible to find any trace of that vessel beyond the point where this extravasation invariably began to show itself: at this place, indeed, the walls of the great artery entirely disappeared, or, rather, became confounded with the membranous septum that here separates the abdomen from the cephalic cavity: neither could any continuity be traced between the arterial trunk, after its entrance into this extensive cavity, and the arteries proceeding from it to ramify in the fleshy portion of the foot, although these latter were invariably well filled with the coloured injection employed; and it soon became evident, from numerous observations, that in this Gasteropod a free communication is normally established between the great arterial trunk of the body and the cephalic cavity, wherein are lodged the principal nervous centres and the whole anterior portion of the digestive apparatus, and that this cavity, in the living animal, is filled with arterial blood. In fact, the aorta having reached the spot where the digestive canal curves downwards to descend from the upper aspect of the pharyngeal bulb into the abdominal cavity, it plunges directly into a wide space or *lacuna* which surrounds the pharynx and occupies all the front part of the head, taking the place of the cephalic portion of the aorta; and the arterial blood poured by that vessel into this space directly bathes the brain, the muscles of the proboscis, and all the anterior part of the alimentary canal, after which it goes to supply the muscles of the foot and the cephalic appendages.

(1424.) But there is one circumstance connected with this arrangement which appears even still more strange, namely that, while a portion of the general cavity of the body thus completes the vascular apparatus, the aorta to a certain extent acts as an abdominal cavity; for in its interior there is lodged a part of the digestive apparatus.

(1425.) To ascertain this fact it is only necessary to slit open the aorta, the calibre of which is in this part as wide as a goose-quill; it is then seen that the large subcylindrical basis of the tongue, which pro-

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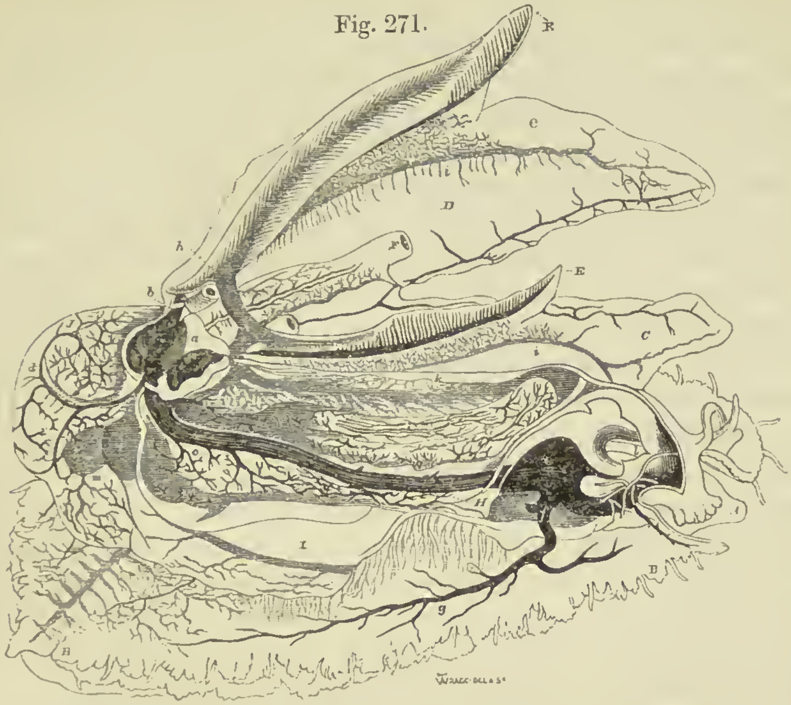
* "Observations sur la Circulation chez les Mollusques," par M. Milne-Edwards (Ann. des Sci. Nat. 1847).

Fig. 271.



Circulation of *Haliotis* (after Milne-Edwards). A, the head; B, the foot; C C, the two lobes of the mantle; D, mucus-secreting organ; E E, the two branchiæ; F, the anus. Beneath the rectum, that terminates at this outlet, is seen the orifice of the urinary apparatus; and a little further back, situated above the intestine, is the orifice of the generative apparatus. G, fold of intestine, which is lodged in a special compartment of the abdominal cavity, separated from that containing the stomach by a fibrous septum. H, the stomach, of which the anterior portion has been in a great measure removed. I, pharyngeal cavity laid open. J, abdomen.

a, aortic ventricle surrounding the rectum.

b, the left auricle, into which opens the efferent vessel of the corresponding branchia, a portion of which is shown at E. The right auricle is seen immediately beneath the ventricle, and the corresponding branchia has been raised in order to show throughout its entire length the branchial vein or efferent canal, E, which runs along the adherent margin of the branchia, and brings arterialized blood from that organ to the heart.

c, the great aorta, which arises from the posterior extremity of the ventricle and runs forward between the stomach and the intestine to discharge itself into the cephalic cavity.

d, the abdominal artery, or posterior aorta, which arises from the commencement of the aorta and follows the convolutions of the intestine, to which, as well as to the liver, it furnishes branches.

e, arterial sinus, into which the aorta empties itself. This is a great cephalic lacuna, limited above by the parietes of the pharynx, in front by the integuments and muscles of the head, and posteriorly by fibro-cellular bands. On injecting the animal by this cephalic chamber, the whole arterial system is immediately filled.

f, the great artery of the foot, which arises from the cephalic sinus, and soon divides into four branches, which extend towards the hinder part of the foot. *g*, one of its lateral branches.

h, afferent vessel of the left branchia. A little in front of the heart is seen the transverse canal, or *common venous reservoir of the branchiæ*, which unites this vessel with its fellow, and which receives the veins from the rectum.

i i, veins of the two lobes of the mantle in communication with a capillary network that extends along the base of the branchiæ, and is proceeding to anastomose with the branchio-cardiac vessels.

k, efferent vessels from the urinary gland opening into the common venous reservoir of the branchiæ.

l, venous canal of the shell-membrane or partition that extends from the walls of the abdomen to the margin of the shell.

m, hepatic veins proceeding to open directly into the free space which surrounds the intestine, and which is continuous with the rest of the abdominal cavity. On the posterior part of the foot are seen veins which open into a system of lacunæ situated upon the median line, and communicating with the abdominal cavity.

jects from the posterior margin of the pharyngeal mass, is entirely enclosed within it. This organ, indeed, protrudes to a considerable distance into the interior of the arterial tube; and it is from the portion of the aorta which thus forms a sheath for the lingual apparatus that several arteries take their origin, the branches of which are distributed to the intestine and abdominal parietes, the orifices of which are discoverable when tho tongue is withdrawn from its aortic sheath.

(1426.) The inforior condition of the circulatory system in the *Haliotis* is, however, not indicated only by the singular arrangements described above. In that portion of the mantle which is adherent to the shell, and which forms a sort of border to the posterior and lateral parts of the body, arterial vessels seem to be altogether wanting, the whole circulation being apparently carried on by vessels which receive venous blood, derived immediately from the abdominal cavity, to which they partially return it, but at the same time convey a portion thereof into the branchio-cardiac vessels in the immediate vicinity of the heart. The fibrous tissue wherein these vessels are enclosed seems but little calculated to perform the functions of an accessory respiratory apparatus; so that it would appear, from this anatomical arrangement, that all the blood in progress towards the heart is not submitted to the influence of the air, and that it is a mixture of venous and arterial blood that is distributed by the heart throughout the arterial system.

(1427.) Lastly, it may be noticed that in the cephalic region, where the different organs are in immediate contact with the arterial blood, no traces are discernible either of veins or of lacunæ serving to return the blood thus effused to the respiratory apparatus, whereas in other parts of the body venons canals are met with, the disposition of which is very remarkable: these all communicate freely with the abdominal cavity, as is the case in other Gasteropod Mollusca; but in the liver, the generative glands, and more especially in the urinary apparatus, they nevertheless form true vessels, the ramifications of which are extremely numerous.

(1428.) In *Patella*, or the Limpet, the sizo of the cephalic sinus that receives blood from the aorta is even more remarkable than in the *Haliotis*: in the *Patella*, indeed, the tongue is not itself lodged in the aorta, as in the former case, but is enclosed in a membranous sheath; the sheath, however, in its turn becomes part of an arterial chamber, into which the aorta empties itself. The aorta itself gives off very few branches, whilo from the lingual sheath arise all the principal arteries of tho body.

(1429.) The arterial blood fills not only the sheath of the tongue, but is likewise diffused throughout the whole cephalic cavity, where it bathes the muscles and nerves in the same manner as in *Haliotis*: but the extent of the sanguiferous sinus is much more considerable than in that mollusk. If, indeed, the capacity of these sinuses be estimated, they will be found to contain more blood than all the rest of the arterial system put together.

(1430.) Such is the construction of the heart in a great majority of the Gasteropoda; but in a few of the lowest orders, namely those most nearly allied to the Conchifera, slight modifications are met with. Thus, in *Chiton* (fig. 263), so remarkable from the singularity of its shelly covering, the heart is situated in the middle of the posterior region of the back, and is furnished with two auricles, one appropriated to each lateral series of branchiæ; and, what is still more remarkable, each auricle would seem to communicate with the ventricle by two distinct orifices. In *Haliotis*, *Fissurella*, and others of the Scutibranchiate and Cyclobranchiate orders, the resemblance to the arrangement generally met with among the Conchifera is even more striking; for in such genera not only are there two distinct auricles, but the ventricle embraces the rectum, so that, when superficially examined, it seems to be perforated for the passage of the intestine.

(1431.) In *Pterotrachea* (fig. 269), the branchiæ (*d*) are placed upon the back, and the blood derived from the tufts composing the branchial apparatus is received into a two-chambered heart (*e*), whence it is distributed to the body through the aorta, which is at first double; but, after surrounding the visceral sac and supplying the viscera, the two vessels unite to form one large trunk (*m*), which traverses the body as far as the head.

(1432.) Independent of the ordinary vascular system, Delle Chiaje discovered the existence in most Gasteropods of a system of water-vessels largely distributed throughout the substance of the foot and other parts of the body. Thus, in the anterior part of the foot of the Muricidæ*, there are to be seen certain holes or antra, which are the apertures to as many little cavities lying underneath, and which permeate the interior substance of the foot. There are, besides, between these cavities slender canals communicating with the same orifices, by means of which the whole are connected and inosculated together. The water entering the body through the siphuncle is thus, at the will of the animal, driven into the substance of the foot, which is in this way rendered turgid and firm; and when necessary, by a strong pressure, the fluid is ejected, or is spontaneously discharged after death, when the foot becomes flaccid and extenuate. Opinions relative to the use of the water thus freely admitted into the body of the Mollusca are various; its principal object, however, seems to be to enlarge and moisten the structures over which it is distributed.

(1433.) The digestive system of the Gasteropoda, as we might be led to expect from the numerous and widely-different forms of the animals belonging to the class under consideration, presents endless diversity of structure; and did we not strictly refrain from noticing any but the most important modifications, it would be easy to overwhelm the most patient reader with accumulated details.

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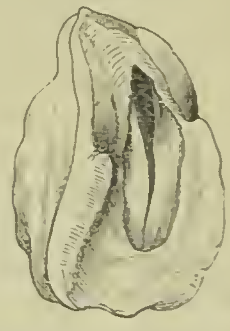
* Delle Chiaje, Anim. senza Vert. d. Nap. ii. p. 204.

(1434.) The mouth we shall consider as exhibiting four distinct types of organization; one of which, namely that met with in the Snail and the generality of pulmonated Gasteropoda, has been already described (§ 1380).

(1435.) The second form of mouth—that, for instance, of *Pleurobranchus* (fig. 267, *a*) and of *Pterotrachea* (fig. 269, *b*)—consists of a simple muscular proboscis, or fleshy tube, which is capable of considerable elongation and contraction: such an oral apparatus is entirely devoid of teeth or any cutting instrument, but is nevertheless fully able to seize and force into the stomach such materials as are used for food.

(1436.) A third kind of mouth, by no means so frequently met with as the last, is not a little extraordinary, and forms a more efficient cutting instrument than even that of the Snail. We shall offer, as an example of this remarkable organ, that of the *Tritonia Hombergii*, represented in the annexed figure (fig. 272), whereof Cuvier gives the following graphic description*. In this animal the mouth forms a large oval and fleshy mass enclosing the jaws and their muscles, as well as a tongue covered with spines; and its opening is guarded by two fleshy lips. The jaws form the basis of all this apparatus: their substance is horny; their colour a yellowish brown; and their form (very extraordinary for an organ of this kind) cannot be better described than by comparing them to the shears used in shearing sheep. They differ, however, in the following particulars:—instead of playing upon a common spring, the two blades are found to work upon a joint, and, instead of being flat, they are slightly curved.

Fig. 272.



Mouth of *Tritonia Hombergii*.

(1437.) These two blades are very sharp, and there is nothing that has life that they cannot cut when the animal causes the cutting edges to glide over each other. For this purpose muscles of great strength are provided, the fibres of which are transverse; and their office is to approximate the two blades, that are again separated by the natural elasticity of the articulation whereby they are united at one extremity.

(1438.) The aliment, once cut by the jaws, is immediately seized by the papillæ of the tongue, which, being sharp and directed backwards, continually drag, by a kind of peristaltic movement, the alimentary materials into the œsophagus.

(1439.) The fourth and most complicated form of mouth is found in the Pectinibranchiate Gasteropods; and with its assistance these animals can bore through the hardest shells in search of food, making a hole as round and smooth as if it had been made by a drill of human contrivance. It is from Cuvier we again borrow the subjoined description of this unique apparatus*.

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* Mémoire sur le Tritonia.

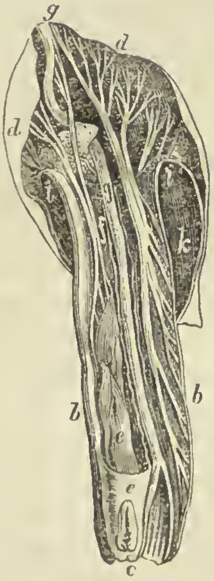
(1440.) The proboscis of *Buccinum* is organized with marvellous artifice. It is not simply provided, like that of the elephant, with the means of flexion and extension, joined with a limited power of contraction and elongation, but it can be entirely retracted into the body by drawing itself into itself in such a manner that the half of it which forms its base contains and encloses the half nearest its point; and it can protrude itself from its sheath thus formed, by unrolling itself like the finger of a glove, or like the horns of the garden snail: only it is never completely retracted, but always remains more or less folded upon itself.

(1441.) It may be represented as being composed of two flexible cylinders, one contained within the other, as shown in the annexed figure (fig. 273), the upper edges (*i i*) of the two cylinders being continuous in such a manner that by drawing out the inner cylinder (*b b*) it becomes elongated at the expense of the other, and on pushing it in again it becomes shorter, while the outer cylinder (*k*) is lengthened by adding to its upper margin.

(1442.) The reader must now imagine a multitude of longitudinal muscles (*d d*), all very much divided at both their extremities, and attached by one end to the parietes of the body, whilst by the opposite they are fixed to the interior of the inner cylinder of the proboscis (*b*) along its entire length and as far as its extremity. It is evident that the action of these muscles will retract this cylinder, and consequently the entire proboscis, into the body.

(1443.) When thus retracted, a great part of the inner surface of the internal cylinder (*b*) will necessarily become a portion of the external surface of the outer cylinder (*k*), and the contrary when the proboscis is protruded. It is in consequence of this that the insertions of the muscles (*d d*) vary in position.

Fig. 273.



Proboscis of *Buccinum*.

(1444.) The protrusion of this proboscis is effected by the action of the circular muscles that form its walls.

(1445.) When the proboscis is extended, the retractor muscles

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* "Mémoire sur le grand Buccin (*Buccinum undatum*), et sur son Anatomie."

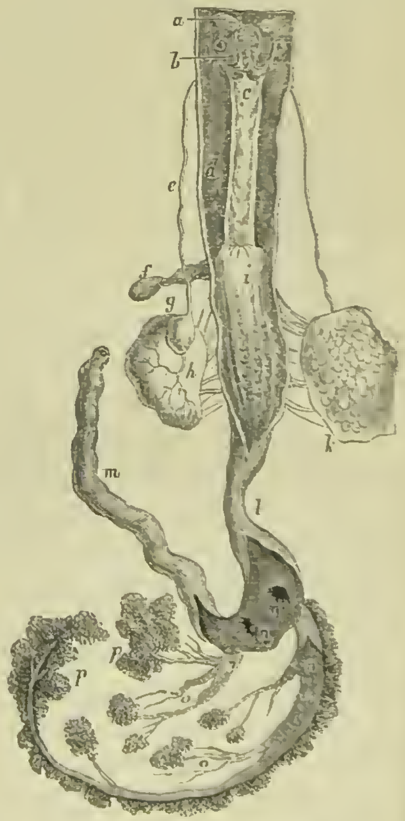
(fig. 273, *d d*), if they do not act altogether, serve to bend it in any direction, thus becoming the antagonists to each other.

(1446.) In the internal cylinder are contained the tongue, with all its apparatus (*e e*), the salivary ducts (*f*), and the greater part of the œsophagus (*g*); but the principal use of the proboscis is to apply the end of the tongue to the surface of bodies that the Buccinum wishes to erode and suck. The tongue itself (*e*) is a cartilaginous membrane, armed with hooked and very sharp spines. It is sustained by two long cartilages, the extremities of which form two lips (*c*), that can be separated or approximated; or the cartilages can be made to move upon each other by the mass of muscles in which they are imbedded. When these cartilages move, the spines that cover the tongue are alternately depressed and elevated; and by a repetition of similar movements, aided perhaps by some solvent quality in the saliva, the hardest shells are soon perforated by this singular file.

(1447.) The salivary glands are lodged in the visceral cavity, and are composed of numerous secerning cæca enclosed in a membranous capsule (fig. 274, *h*, *k*): their ducts (*g*, *e*), which are necessarily as long as the proboscis when extended to the utmost, open by two apertures placed at the sides of the spinous tongue (*b*). The œsophagus (fig. 273, *g g*) runs along the centre of the proboscis throughout its entire length, and, when that organ is protruded, becomes nearly straight; but when the proboscis is drawn in, the œsophagus is folded upon itself among the viscera.

(1448.) Just at the commencement of the stomach there is a small crop (fig. 274, *f*); and the stomach itself is single, without anything in its texture requiring special notice,—its lining membrane being soft, and gathered into longitudinal folds (*i*).

Fig. 274.



Alimentary canal of *Buccinum*.

(1449.) Equally simple is the alimentary apparatus of the *Heteropoda*. In these the stomach (fig. 269, *f*) is a mere dilatation of an intestiniform tube. The intestine is not lodged in the general cavity of the body, but, with the mass of the liver, is contained in a kind of bag attached to the back of these singularly-formed animals, and in some genera, as for example *Carinaria*, is defended by a delicate transparent shell, which in appearance offers a miniature resemblance to the Argonaut. It is in this visceral sac that the heart and generative apparatus are likewise generally enclosed; but in many forms of the Heteropoda both the appended sacculus and shell are wanting, in which case the viscera are, of course, lodged in the general cavity of the body.

(1450.) But although in *Buccinum, Pterotrachea*, and kindred genera the stomach is thus devoid of complication, it is by no means unfrequently found to be provided with a powerful crushing apparatus, that forms a strong gizzard, adapted to bruise, cut, or tear the food introduced into it. In *Scyllæa*, for example, this gizzard, situated at the entrance to the stomach, contains twelve horny cutting blades, disposed around its interior and arranged in a longitudinal direction; their sharp edges therefore, meeting in the centre, efficiently divide whatever passes between them towards the proper digestive stomach. In *Aplysia* there is first a capacious crop, then a strong gizzard studded internally with pyramidal blunt teeth; and to this succeeds a third cavity armed with sharp-pointed hooks attached to one side of its walls, and so disposed as to form a kind of carding-machine, by which the food is still more effectually torn to pieces.

(1451.) Various modifications in the form and structure of these stomachal teeth are met with in the different genera of the Gasteropoda that possess such an apparatus; but whatever their shape, size, number, or position, the office assigned to them is the same.

(1452.) The liver is proportionately of very large size in the Mollusca we are now describing. Its composition is similar in all, being made up of bunches of secreting follicles united by the branches of their excretory ducts, and kept together by means of a delicate cellulosity and the ramifications of blood-vessels. We have already described the hepatic viscera of the Snail; and the liver of *Buccinum*, unravelled so as to show its intimate structure, is represented in the preceding figure (fig. 274, *n, o, p*), which requires no additional explanation.

(1453.) But if the structure of the liver is similar in all the Gasteropod Mollusca, the manner in which the bile is poured into the intestine varies remarkably. The most ordinary position of the orifices of the hepatic ducts is at the termination of the stomach, in the vicinity of the pylorus, as is the case in the majority of other animals; but many exceptions to this rule are met with in the class before us.

(1454.) In *Scyllæa* the bile is poured into the œsophagus just before it terminates in the gizzard; in many genera the biliary canals open into the stomach itself; and in one remarkable genus, *Onchidium*, there are three distinct livers, each provided with its proper excretory duct, and, what is still more anomalous, these three glands, which in every particular strictly resemble each other, unless perhaps in size, pour the secretion that they furnish into three different situations,—the first into the œsophagus; the second into the œsophagus likewise, and the third into the gizzard, which forms the first of three stomachal cavities.

(1455.) In *Doris*, a figure of which is given above, a still more extraordinary arrangement is met with. One set of ducts derived from the liver penetrate the stomach, and pour the bile into that cavity, while another large canal, equally given off from the liver, terminates at the exterior of the body by an orifice situated in the vicinity of the anus (fig. 266); and thus a part of the bile secreted would seem to be expelled from the system as excrementitious matter—a fact of no ordinary importance to the physiologist, as it would itself go far to prove that the function of the liver is not merely limited to the supply of a secretion of importance in the digestion of food, but that it powerfully cooperates with the respiratory system in purifying the circulating fluids by decarbonizing the blood.

(1456.) Other secretions, apparently of an excrementitious character, are furnished by many Gasteropods. Thus, in *Aplysia* a glandular mass is imbedded in the opercular flap that protects the gills, from which, at the pleasure of the animal, a reddish liquor is made to exude in sufficient abundance to obscure the water around it, and thus conceal it from pursuit. Another gland furnishes an acrid limpid fluid, that distils from an orifice near the oviduct; but the use of this last secretion is as yet unknown.

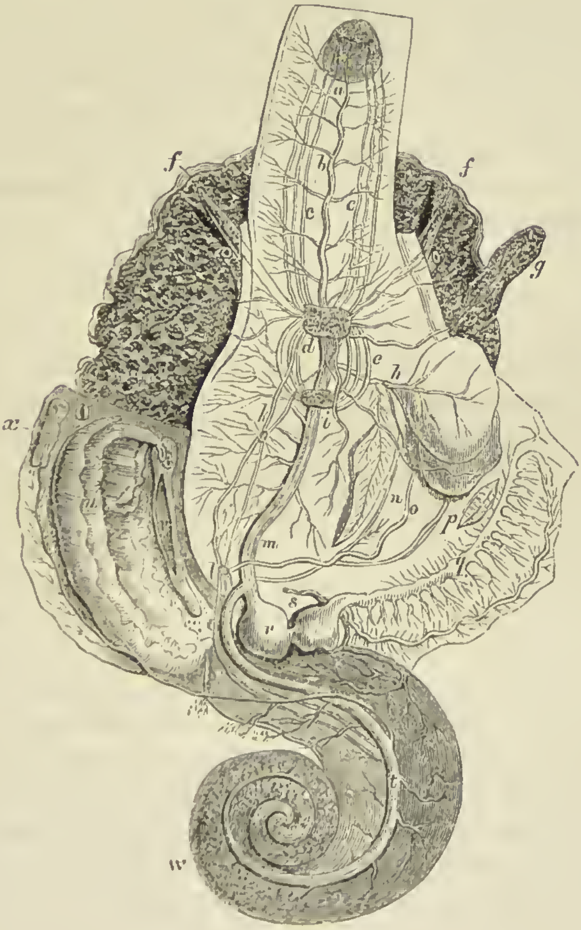
(1457.) The scattered condition of the nervous ganglia, characteristic of the HETEROGANGLIATA, is well exhibited in the Pectinibranchiate Gasteropods, more especially as it not unfrequently happens that the ganglionic centres themselves are of an orange or reddish colour, while the nerves derived from them present their usual appearance.

(1458.) In *Buccinum* the brain still occupies its usual position above the œsophagus (fig. 275, *d*), and gives off nerves to the organs of sensation, and large twigs (*c c*) to the eminently sensitive proboscis. A large nervous mass placed beneath the œsophagus (*i*) is connected with the former by several communicating nerves that embrace the œsophageal tube. Other ganglia, of smaller size (*k*, *l*, *n*), are distributed in distant parts of the body, and supply the viscera to which they are contiguous, whilst they are connected among themselves, and with the brain, by nervous cords passing from one to another.

(1459.) In *Pterotrachea* the same dispersion of the central ganglia of the nervous system is equally evident. The brain and nervous collar around the œsophagus occupy their usual situation, and give nerves to the tentacles, eyes, and parts around the mouth: while four smaller ganglia (fig. 269, *i*) are placed in the immediate vicinity of the foot, to which and to the neighbouring viscera they distribute their branches.

(1460.) But in the most elevated Gasteropods the ganglia assume greater concentration, and the brain exhibits much larger dimensions as compared with the size of the body. Thus, in the Snail (fig. 265) we find only two great nervous masses—the brain (*l*) (a large ganglion placed above the œsophagus, and supplying the nerves connected with sensation), and an equally large subœsophageal mass (*m*), whence proceed nerves to all the viscera and locomotive organs. Here, therefore, we have another example of the great law that we have already so often illustrated—the diminution in number and the increase in size of the nervous centres as we rise from lower to more exalted types of animal organization.

Fig. 275.



Anatomy of *Buccinum*.

(1461.) The tentacula (fig. 275, *f f*) in the marine Gasteropoda are generally not retractile, and the eyes are frequently situated at the outer side of the base of each tentacle, instead of at their apex as in the figure referred to; but, with these exceptions, we can add nothing to what has been said concerning the senses of these Mollusca in the description of the Snail already given as an example of the general structure of the entire class.

(1462.) The organ of hearing is now universally admitted to exist in all the Gasteropod Mollusca, and, according to Siebold*, is invariably situated in the immediate vicinity of the two most voluminous cerebral masses. Like the other organs of sense, the organ is always double. It is formed† by two hyaline ovate or orbicular capsules, situated on the head or neck at the bases of the tentacula, and is supplied with its specifically-endowed nerve from the cerebral ganglions. In the capsule there are enclosed one or several (and sometimes they are numerous) oval or round crystalline bodies, named otoliths; and it is observable that the number varies not only in neighbouring genera, but even in nearly-allied species. Siebold says that a concentric depression is evident in these otoliths, and there may be seen, in the greater number of them, a shaded spot, or, rather, a minute aperture, which penetrates through the concretion from the one flattened surface to the other. Subjected to a strong pressure, the otoliths crack in radiating lines, separating often into four pyramidal pieces. This separation also ensues when the otoliths are immersed in diluted nitric acid; and if we touch them with the concentrated acid, they suddenly dissolve, with the disengagement of a gas, whence Siebold concludes them to be composed of carbonate of lime. The size of the otoliths is not equal; and in the same capsule there are always some which are smaller than others. Within the capsule they have, during life, a very remarkable, and in some respects peculiar, lively oscillatory movement, being driven about as particles of any light insoluble powder might be in boiling water. The otoliths in the centre have the appearance of being pressed together, so as to form a sort of solid nucleus; and towards this centre the otoliths seem ever to be violently urged, their centripetal rush being invariably repulsed, and themselves driven back again in a centrifugal direction. Removed from the capsule, the motions of the otoliths instantly cease. The cause of these curious oscillations remains undiscovered. Siebold could detect no vibratile cilia on the surfaces of the capsule‡; and the cessation of the motion when the otoliths are removed proves them to be unciliated themselves, and at the same time distinguishes the motion from that of inorganic molecules, as described by Mr. Brown.

(1463.) Dr. Nordmann, in an elaborate memoir on the anatomy of the *Tergipes Edwardsii*, minutely describes the structure of the auditory capsules of that species, in which they are found situated immediately behind the eyes, upon the posterior portion of the two anterior ganglia, and are at once recognizable by their sharp outline and very considerable size, which surpasses that of the eyes themselves. The proper auditory nerves are wanting, the vesicles of hearing being lodged in little excavations in the ganglia themselves. These vesicles, which are of a round or oval shape, consist of a thin vitreous-looking membrane (but which is sufficiently tough to resist considerable pressure), and contain a fluid in which is suspended a minute rounded otolith.

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* Ann. des Sci. Nat. 1843, xix. p. 198.

† Introduction to Conchology; or, Elements of the Natural History of Molluscous Animals, by George Johnston, M.D., LL.D., to which the student is referred, as being by far the best treatise upon the subject in the English language, for fuller details concerning the habits and organization of the Mollusca.

‡ Kölliker has observed that the motion of the otoliths in the Mollusca is dependent upon cilia, with which the internal surface of the auditory cyst is covered.

(1464.) We now approach an inquiry of much interest as concerns the economy of the animals before us—namely the varied forms of their organs of reproduction, and the character of the generative system belonging to each order. This investigation, however, is one of no ordinary difficulty; for so numerous are the modifications of structure observable in almost every genus, that, were we not strictly to confine ourselves to the study of the most prominent and important features of this portion of their history, the patience of the student would be severely put to the test in following us through all the details connected with so extensive a subject.

(1465.) The three lowest orders of the GASTEROPODA are still, in many particulars, more or less allied to the CONCHIFERA; but more especially this is the case in the organization of their generative apparatus. The *Cyclobranchiata*, *Scutibranchiata*, and *Tubulibranchiata*, like the inhabitants of bivalve shells, are all hermaphrodite and self-impregnating *. A large granular ovary is in all these orders imbedded in the mass of the liver; and from this a duct leads to an external orifice situated in the vicinity of the anus: if impregnation is in such animals essential to fecundity, the fertilizing secretion must be furnished by the glandular walls of the oviduct, as no male organs have as yet been discovered.

(1466.) The *Pectinibranchiata*, on the contrary, are all diœcious,—the sexes being distinct, and intercourse between the male and female necessary for the impregnation of the latter.

(1467.) The male is generally at once distinguished by the penis, appended to the right side of the neck (fig. 275, *g*), an organ which is frequently of enormous proportions—so large, indeed, that, it being impossible that it should be retracted into the body, it is generally simply folded back into the branchial chamber. The testicle is imbedded in the mass of the liver, and lodged in the inmost recesses of the shell. It gives origin to a long and very tortuous vas deferens, which is at first extremely slender, but on emerging from the mass of the viscera becomes thicker, running along the right side of the body until it enters the penis, and, having made many zigzag folds, reaches the extremity of that organ, where it terminates by a small orifice.

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* The announcement of the discovery of *spermatozoa* in individuals belonging to these orders, mentioned in a former page, will, perhaps, materially modify the opinions of physiologists upon this point.

(1468.) Equally simple is the structure of the generative system in the females of the Pectinibranchiate Gasteropods. A large ovary occupies the same position as the testis of the male, and shares with the liver the interior of the windings of the shell. The oviduct generally follows the same course as the vas deferens of the other sex, and is provided with thick and glandular walls. The eggs, which are very numerous, are arranged in long gelatinous ribands, and, after extrusion, are glued in various ways to the surface of rocks, sea-weed, or even to the shells of other Mollusca. Sometimes, in the siphoniferous tribes, as for example in the common Whelk (*Buccinum*), the ova are enclosed in tough coriaceous capsules secreted by a glandular organ in the vicinity of the oviduct. These capsules contain several eggs apiece, and are joined together in large bunches, such as the waves continually cast up upon every beach.

(1469.) The *Heteropod Gasteropoda* are hermaphrodite. In *Pterotrachea* the female organs consist of a distinct ovary, uterus, spermatheca, and an auxiliary gland, all lodged in the visceral sacculus appended to the back. The ovary (fig. 269, *p*) is of considerable size, and gives origin to a slender oviduct, which, near its termination, communicates with the receptacle for the ova, called the *uterus* (*g*). The spermatheca joins the canal leading from the uterine cavity to the exterior of the body, which likewise receives the secretion of two small glandular sacs (*k*) apparently destined to furnish some investment to the eggs prior to their expulsion.

(1470.) The male parts are situated in the general cavity of the body, quite apart from the female apparatus. The testicles seem to be represented by two wavy cæca (fig. 269, *t*), which terminate at the root of a small intromittent organ (*s*) placed at a short distance behind the opening of the vulva.

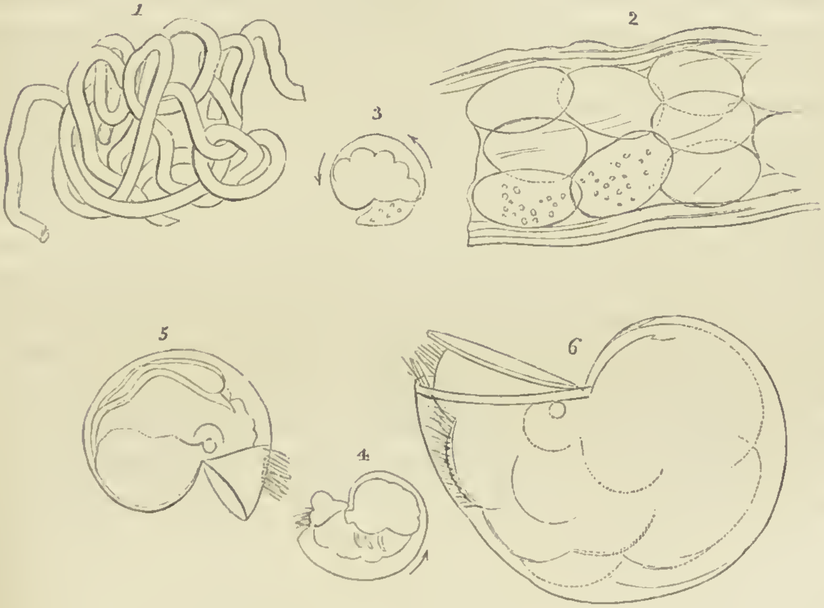
(1471.) All the *Tectibranchiata, Inferobranchiata, Nudibranchiata*, and the *Pulmonated Gasteropods* are hermaphrodite, having both a male and female generative apparatus arranged upon the same principles as those of the Snail, which have already been described at length: and to enumerate the variations which occur in the relative position and organization of different parts of the reproductive system in all the genera composing these extensive orders would scarcely answer any useful purpose, even were it practicable within the limits of this work.

(1472.) In the male *Patella*, the testicle is situated upon the right side of the body, between the visceral mass and the external envelope. It is of a pale-yellow colour, with a slight pinkish tint, and seems to be entirely made up of minute tubes, many times folded upon themselves, and imbedded in a granular-looking substance. On cutting into the substance of the testicle, there flows out a milky fluid, which the microscope reveals to contain innumerable spermatozoa, whose movements are very active as long as the seminal secretion is fresh.

(1473.) The ovary of the female occupies nearly the same situation as the male testis; but all attempts to trace the excretory duct of either have as yet proved futile.

(1474.) When the ova of the Nudibranchiate Mollusca are placed under the microscope soon after the extrusion of the spawn, each is seen to consist of a thin transparent *case-membrane**, with a round smooth and opake body in its centre (the ovum proper), which is chiefly composed of minute cells enclosed in a vitelline membrane. These ova vary in size from $\frac{1}{250}$th to $\frac{1}{280}$th of an inch in diameter. A few hours after the extrusion of the spawn the yelk divides by progressive segmentation until the end of the fifth day, when the division of the cells appears to have reached its utmost limit and the vitelline mass has changed its shape, having become broader at one end, narrower at the other (fig. 276, 2). At the end of the sixth day no additional change takes place in the external form of the ovum, but the cells into which it has divided continue to coalesce, and minute cilia become apparent on the upper surface of the broad extremity. On the eighth day it assumes the form represented at fig. 276, 3, its circumference becomes more or less translucent, and the external layer of cells seems to separate from the rest to form the commencement of the shell (fig. 276, 4), the cilia on the broad extremity become larger and more active in their movements, and traces are observed of the division of this end into *ciliated disks*: it is now entitled to the name of *embryo*.

Fig. 276.



Development of the embryo of a Nudibranchiate Mollusk. 1. Gelatinous coil, in which the ova are imbedded. 2. A portion of the same, magnified. 4, 5. Embryos in different stages of growth. 6. Mature embryo when newly hatched, enclosed in a minute nautiloid shell.

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* This *case-membrane* is not the homologue of the ordinary egg-shell, seeing that it sometimes encloses two, three, four, or even five ova.

(1475.) From the ninth to the eleventh day the ciliated disks become more developed, more separated from each other, and more moveable; the largest of the four lobes of the body has arranged itself into stomach and intestine, in which occasional contractile movements may be seen.

(1476.) The case-membrane previous to the escape of the embryo becomes gradually thinner, and at last either entirely disappears or is reduced to shreds, probably by the incessant strokes upon its inner surface of the long cilia of the ciliated disks during the active revolutions of the embryo round its interior. The embryo at the time of its liberation is provided with a shell somewhat resembling that of the Nautilus, from which it can protrude the anterior part of its body and retract it at pleasure (fig. 276, 6), swimming about actively in the surrounding water by means of its ciliated disks.

(1477.) The spawn of other Gasteropods is deposited under diverse forms. In the marine species it is usually found attached to the surface of stones, shells, or sea-weed, the ova being connected with each other in long ribands or delicate festoons, which are sometimes extremely beautiful and curious. The *Doris* and *Tritonia* deposit their ova in long gelatinous bands, resembling beautiful frills of rich lace. In *Aplysia* the spawn resembles long strings of jelly, in which the ova are seen, varying in tint, so as to give different colours to different parts of the thread. In *Helix* and *Bulimus* the eggs are protected by a hard shell; whilst in *Buccinum*, *Voluta*, *Murex*, and other marine species the ova are enveloped in membranous capsules, agglomerated together in large bunches. These capsules have been sometimes erroneously regarded as the eggs themselves; they are, however, merely coriaceous envelopes, answering the purpose of the gelatinous coating that encloses the eggs of other species. Many of the Gasteropoda are exceedingly prolific: a single *Doris* will lay 50,000 eggs at a birth; and when we take into account that all the individuals are prolific (the sexes being combined), and that each will produce spawn two or three times in a season, it is evident how vast must be the number of their progeny.

CHAPTER XXIII.

PTEROPODA* (Cuvier).

(1478.) Nearly allied to the Gasteropods in their internal organization, but differing from them remarkably in the character and position of their locomotive apparatus, are the Pteropoda—a class of mollusks of small dimensions, but met with in astonishing quantities, at certain seasons, in various parts of the ocean. So numberless, indeed, are these little beings in those regions where they are common, that the surface of the sea seems literally alive with their gambollings; and thus the store of provisions necessary to render the waters of the ocean habitable to animals of higher grade in the scale of life is still further increased. The great character that distinguishes the members of the class upon the investigation of which we are now entering is derived from the structure of their organs of locomotion. These are only adapted for swimming, and consist of two broad and fleshy expansions, attached like a pair of wings to the sides of the neck, and forming moveable fins—enabling the little beings to dance merrily among the foamy waves, now sinking, and again rising to the surface, until some passing whale, opening its enormous jaws, engulfs multitudes of such tiny victims, and hence derives the materials for its subsistence.

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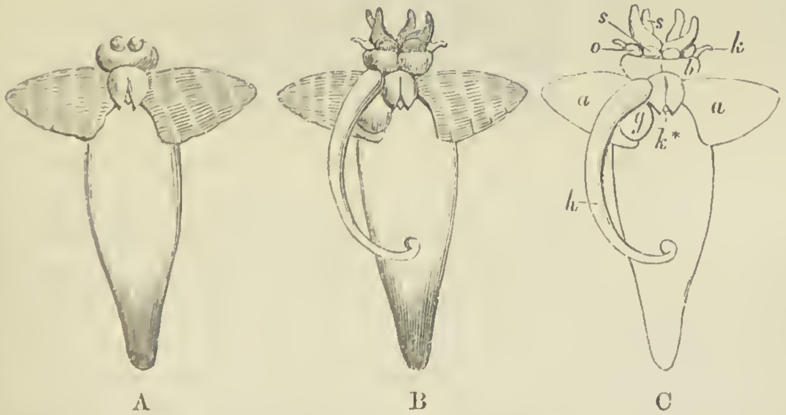
* πτερὸν, a wing; ποῦς, ποδὸς, the foot.

(1479.) Several distinct genera of Pteropoda have been established by zoologists, and some important modifications have been detected in their organization, although in all of them the lateral alæ form the instruments of progression.

(1480.) The *Clio borealis*, anatomized by Cuvier *, and more recently and completely investigated by Professor Eschricht of Copenhagen †, is one of the species best known, as well as most abundantly met with; it is therefore by a description of this Pteropod that we shall proceed to introduce the reader to the general facts connected with the history of the animals under consideration.

Fig. 277.



Clio borealis; represented at A in a state of repose, while B, C exhibit the various external appendages fully protruded: *a a*, wing-like oars; *b*, hood retracted; *g*, bladder-like organ; *h*, penis; *k*, tentacle; *o*, globular protuberances; *s s*, conical appendages.

(1481.) The body of the *Clio* is about an inch in length, of an oblong shape, and terminating posteriorly in a point; while at the opposite extremity there is a little head supported upon a short neck, and furnished with delicate retractile tentacles, apparently instruments of touch. The locomotive organs, as the name of the class imports, consist of two delicate wing-like appendages (fig. 277, *a a*) attached to the two sides of the neck, by means of which, as by a pair of broad fins, the Pteropod rows itself about with facility. But the two aliform membranes, although externally they appear separate instruments, are, as we are assured by the observations of Professor Eschricht, but one organ, being made up entirely of muscular fasciculi, which pass right through the neck and spread out on each side in the substance of the wing, forming an apparatus exactly comparable to the double-barrelled oar with which the Greenlander so dexterously steers his kajac, or canoe, through the very seas inhabited by the little *Clio* we are describing.

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* Mémoire sur le *Clio borealis*.

† Anatomische Untersuchungen über die *Clione borealis*, von D. F. Eschricht. Kopenhagen, 1838, 4to.

(1482.) The head of one of these animals is surmounted by various organs appropriated to different offices, and some of them not a little remarkable from the amazing complication of structure which they exhibit. On each side of the oral opening are three conical appendages (fig. 277, c, *s*), that to a superficial examiner might appear to be mere fleshy tentacula; but in reality they are instruments of prehension, of unparalleled beauty and astonishing construction. Each of these six appendages, when examined attentively, is seen to be of a reddish tint: and this colour, under the microscope, is found to be dependent upon the presence of numerous minute isolated red points distributed over its surface. When still further magnified, these detached points are evidently distinct organs, placed with great regularity, so as to give a speckled appearance to the whole of the conical appendage; and their number, at a rough guess, may be estimated at about three thousand. Every one of these minute specks is, in fact, when more closely examined, a transparent cylinder, resembling the cell of a polyp, and containing within its cavity about twenty pedunculated disks, which may be protruded from the orifice of their sheath (fig. 278, c), and form so many prehensile suckers adapted to seize and hold minute prey. Thus, therefore, there will be 3000 × 20 × 6 = 360,000 of these microscopic suckers upon the head of one *Clio*—an apparatus for prehension perhaps unparalleled in the creation.

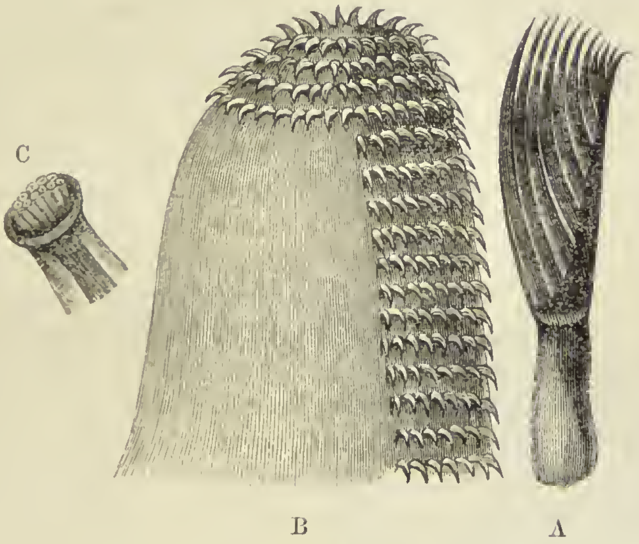
(1483.) When not in use, the appendages referred to are withdrawn, and concealed by two hood-like fleshy expansions, which, meeting each other in the mesial line, completely cover and protect the whole of this delicate mechanism, as represented in (fig. 277, A).

(1484.) Still, however, even when the hoods are drawn over the parts they are intended to defend, the *Clio* is not left without tactile organs wherewith to examine external objects; for each valve of the hood is perforated near its centre: and through the apertures so formed, two slender filiform tentacula (fig. 277, c, *k*), somewhat resembling the feelers of a Snail, are protruded at the will of the animal; and by means of these it is informed of the presence of food, and instructed when to uncover the elaborately-organized suctorial apparatus destined to seize it and convey it into the mouth.

(1485.) The mouth itself is described by Cuvier as being a simple triangular opening, resembling the wound inflicted by a troçar; and in the solitary specimen at his disposal he did not succeed in detecting any dental structures. Eschricht, however, with superior opportunities, was more successful in displaying the oral organs, and found the *Clio* to possess jaws of very singular conformation, and a tongue covered, as in many other Mollusca, with sharp horny spines.

(1486.) One of the jaws removed from the body, and magnified twenty-eight diameters, is represented in the subjoined figure (fig. 278, A). It consists of a series of sharp horny teeth of unequal length, fixed to the sides of a lateral pedicle in such a manner that their points are all nearly at the same level. The teeth themselves have a golden metallic lustre, and, when examined in the sunshine under water by means of a lens, are especially beautiful objects. The basis to which they are fixed is apparently of a fleshy character, and if smashed by being squeezed between two plates of glass, and then placed under the microscope, appears to be made up of a multitude of regularly-disposed fibres that cross each other in two principal directions.

Fig. 278.



A, one of the jaws of *Clio borealis*. B, the tongue, with its recurved spines. C, cylinder enclosing the prehensile suckers.

(1487.) The jaws thus constructed are placed on each side of the mouth, contained in two hollow curved cylinders, the walls of which are muscular; and if one of these muscular capsules be snipped by means of a pair of very fine scissors, the strangely-formed jaw, with its teeth, is found lodged within it.

(1488.) The manner in which the *Clio* uses these dental organs is obvious from their anatomical position. The curved muscular cylinders by the contraction of their walls force out the teeth, so that they then project from the mouth, and are ready to seize and drag into the oral orifice whatever food presents itself.

(1489.) Once conveyed by the jaws into the interior of the mouth, the prey seized is taken hold of by the tongue; the free extremity and upper surface of which is seen, when highly magnified, to be covered with regular rows of spiny hooklets, all directed backwards, and evidently intended to assist in deglutition (fig. 278, B).

(1490.) The structure of the alimentary canal is extremely simple. The œsophagus (fig. 279, *t*) gradually dilates into a wide stomachal cavity that is surrounded on all sides by the mass of the liver; while the intestine (*v*), in which the stomach terminates, mounting towards the left side of the neck, ends by an external anal orifice. Two long and slender salivary glands (*w*) are placed at the sides of the œsophagus, and furnish a secretion that is poured into the mouth. The precise character of the bile-ducts has not been satisfactorily determined in *Clio*; but in *Pneumodermon*, another Pteropod very nearly allied to the genus we are describing, the stomach itself, which is enveloped on all sides by the liver, receives the biliary secretion through a multitude of minute pores.

(1491.) With respect to the real nature of the respiratory apparatus in *Clio*, much doubt exists. Cuvier regarded the aliform fins as being subservient to respiration, as well as forming locomotive organs, and observes that the surfaces of these appendages, seen with the microscope, present a network of vessels so regular, so close, and so delicate, that it is not possible to doubt that they are intended to perform the functions of a respiratory apparatus, adding, moreover, that their connexion with the internal vessels and the heart confirms this view of the nature of these membranes.

(1492.) Eschricht, on the contrary, denies altogether the existence of any such vascular ramifications as Cuvier describes, asserting that the appearance alluded to is entirely produced by the spreading out of the muscular fibres above-mentioned, and that the only vessels visible in the alar processes are a few arterial branches derived from the aorta.

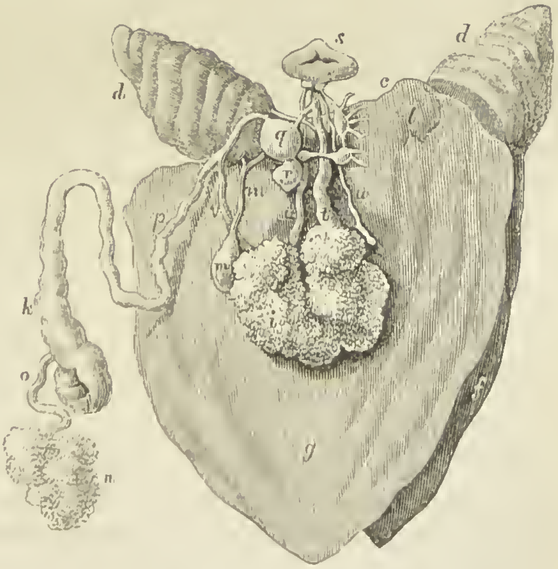
(1493.) We are still, therefore, in ignorance as to the respiratory organs of *Clio*: the heart, however, is very apparent: it is composed of a single auricle and ventricle, enclosed in a pericardium (fig. 279, *m*), and gives off at one extremity a large vessel (*m*), which Cuvier regarded as a pulmonary vein, but which Eschricht has proved to be the aorta, inasmuch as he has traced its branches to the liver and the other internal viscera of the body.

(1494.) The nervous system of this mollusk is easily distinguished, not only on account of the large proportionate size of the ganglia, but from the circumstance of the nerves being of a pale-red colour. The ganglia form a ring placed around the œsophagus near the middle of the neck. There are eight large and two smaller ganglionic masses closely aggregated in this situation; and from these sources all the nerves of the body are given off.

(1495.) From the large dimensions of the nervous centres, we may be prepared to expect senses of correspondent perfection of structure. We have already mentioned the sensitive tentacula protruded from the hood-like covers that protect the oral apparatus; but, in addition to these, organs of vision are provided, apparently of a very complete character. These eyes are two in number, and are placed on the back of the neck. Each eye has the form of a somewhat bent cylinder, having its two extremities rounded off. The anterior end of the cylinder is the transparent cornea; and when the eye is removed from the body of the animal and examined under the microscope by transmitted light, sundry parts may be detected in its interior—sufficient, indeed, to indicate the existence of a choroid membrane, a vitreous humour, and a distinct lens, occupying the ordinary positions of these parts of the visual apparatus.

(1496.) The generative system of *Clio* resembles in all essential particulars that of the most highly organized Gasteropoda, and, as in them, is composed of a complete set of male organs as well as of ovigerous viscera. According to the views which Cuvier was led to entertain from the dissection of a single specimen, he supposed that the ovary (fig. 279, *n*) gave off a slender oviduct (*o*) terminating in a thick glandular canal, the testicle (*k*), which, beginning by a cæcal prolongation, and gradually diminishing in diameter until it became attenuated into a slender *vas deferens* (*p*), ultimately emptied itself into a small round sac (*q*) situated in one side of the neck, where it communicated with the exterior. Close to the sac (*q*) the illustrious

Fig. 279.



Viscera of *Clio borealis*: *m m*, the heart, giving off a large vessel; *l*, œsophagus; *v*, intestine; *u*, salivary glands; *n*, ovary; *o*, oviduct; *k*, testicle; *p*, its excretory canal; *q*, bladder-like organ.

French anatomist pointed out another vesicle (r), which he compared to the *bladder* (*spermatheca*) of Gasteropod Mollusks. The more complete researches of Professor Eschricht have, however, rendered considerable modifications of the above description requisite, inasmuch as that gentleman has succeeded not only in detecting a testis quite distinct from the ovigerous canal, but also a very complete intromittent apparatus. The testis, in fact, in a fresh specimen is so large as to occupy a great portion of the visceral cavity; and, no doubt, in the individual examined by Cuvier, which had been kept in spirits of wine, it formed a large portion of the mass (fig. 279, i) which he thought to be entirely made up of the liver. The duct from this testis communicates with the receptacle (q); so that the glandular canal (k) must be regarded as a part of the oviduct analogous to what has been called the *uterus* in the Snail.

(1497.) Another important discovery for which science is indebted to the Danish Professor is that the *Clio* possesses a long and singularly-formed penis (fig. 277, c, h), lodged, when retracted, in the interior of the head of the Pteropod, but which, together with the bladder (g), in which it was contained, can be extruded from the right side of the neck to such an extent that it nearly equals in length the whole body of the little creature.

(1498.) The mass formed by the viscera occupies but a small space in the general cavity of the body. The external investment of the visceral sac is a thin semitransparent skin (fig. 279, f) of soft texture: and within this is a second covering (g), thicker than the first, and exhibiting very distinct muscular fibres, principally distributed in a longitudinal direction, so that their action would seem to shorten the animal and make its shape more spherical.

(1499.) What fills up the space that intervenes between the muscular tunic and the viscera is as yet undetermined; but Cuvier, in the memoir above referred to, suggests that it may possibly contain air, which, as it should be compressed or allowed to expand, would form a kind of swimming-bladder, and allow the animal to mount to the surface, or sink into the recesses of the sea, with little effort or exertion of muscular power.

(1500.) The other genera included in this class agree in their general form, and in the arrangement of their digestive and reproductive organs, with *Clio* above described, but present a few important modifications in the disposition of their branchiæ, and other minor circumstances.

(1501.) In *Hyalæa* the mantle contains a shell composed of two unequal plates, one of which is dorsal, and the other ventral; and the branchiæ, which are here distinctly recognizable, form a circle of vascular leaflets enclosed in a cavity of the mantle situated between the divisions of the shell, and so disposed that the water has free admission to them through the two lateral fissures of its testaceous defence.

(1502.) In *Pneumodermon*, again, the branchiæ occupy a totally different situation, the branchial leaflets being arranged in semicircular lines upon the posterior extremity of the animal; but such modifications of a general type of structure are of more interest to the zoologist than to the physiological reader, and our space warns us that we have yet to encounter forms of life widely different from any that have hitherto fallen under our notice.

CHAPTER XXIV.

CEPHALOPODA* (Cuvier).

(1503.) We now arrive at the highest order of Mollusca, composed of animals distinguished by most strange and paradoxical characters, and exhibiting forms so uncouth, that the young zoologist who for the first time encounters one of these creatures may well be startled at the anomalous appearance presented by beings so remote in their external construction from everything with which he has been familiar.

(1504.) Let him conceive an animal whose body is a closed bag, containing the viscera connected with digestion, circulation, and reproduction, furnished with a head and staring eyes—that upon the head are supported numerous and complex organs of locomotion, used as feet or instruments of prehension—moreover, that in the centre of the locomotive apparatus, thus singularly situated, is a strong and sharp horny beak resembling that of a parrot—and he will rudely picture to himself a Cephalopod, such as we are now about to describe.

(1505.) The *Octopus vulgaris*, or common *Poulpe*, represented in the next figure, will serve as an example calculated to prove, we apprehend, that the above is no exaggerated statement; and should the student unexpectedly observe an animal of this kind walking towards him upon the beach in the position there delineated, his curiosity would doubtless be excited to learn something of its habits and economy.

(1506.) Yet not only can the Poulpe walk in the manner exhibited in the subjoined figure (fig. 280), but it is well able to swim, if occasion require,—the broad fleshy expansion that connects the bases of its eight legs being fully adequate to enable it to adopt such a mode of progression; for, by vigorous flappings of this extensive organ, the animal actively impels itself through the water in a backward direction and shoots along with wonderful facility.

(1507.) The feet or tentacula appended to the head are not, however, exclusively destined to effect locomotion: they are used, if required, as agents in seizing prey, and are of so terrible a character, that, armed with these formidable organs, the Poulpe becomes one of the most destructive inhabitants of the sea; for neither superior strength nor activity, nor even defensive armour is sufficient to save its victims from the ruthless ferocity of such a foe. A hundred and twenty pairs of suckers, more perfect and efficacious than the cupping-glasses of human contrivance, crowd the lower surface of every one of the eight flexible arms. If the Poulpe but touch its prey, it is enough: once a few of these tenacious suckers get firm hold, the swiftness of the fish is unavailing, as it is soon trammelled on all sides by the firmly-holding tentacula and dragged to the mouth of its destroyer. The shell of the Lobster or of the Crab is a vain protection, for the hard and crooked beak of the Cephalopod easily breaks to pieces the frail armour; and even man himself, while bathing, has been entwined by the strong arms of gigantic species, and struggled in vain against a grasp so pertinacious.

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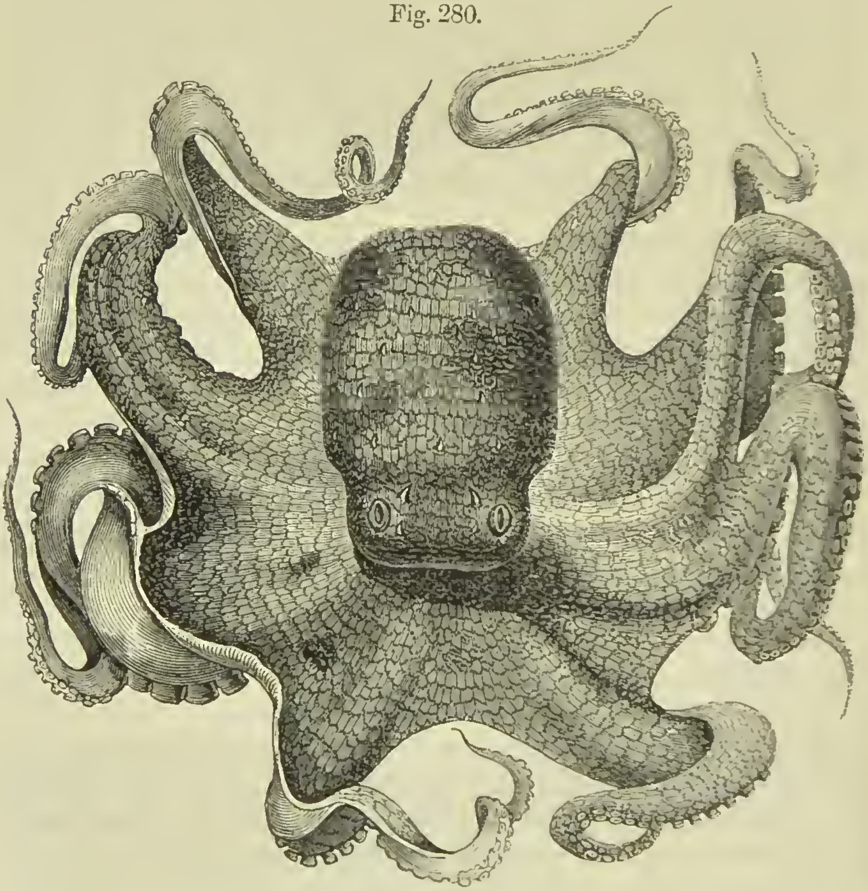
* κεφαλή, the head; πους, ποδὸς, the foot.

Fig. 280.



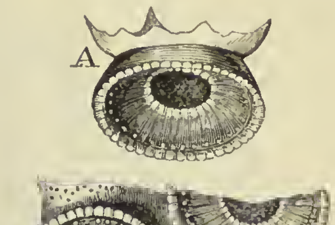
The Poulpe (*Octopus vulgaris*).

(1508.) In the genus *Octopus* the arms are only eight in number, and nearly of equal length; but to the Calamaries (*Loligo*) and other genera an additional pair is given, which, being prolonged considerably beyond the rest, are not merely useful for seizing prey at a distance, but become convertible to other purposes, and may be employed as cables whereby the Cephalopods so furnished ride securely at anchor in a tempestuous sea,—the suckers being placed upon an expanded disk, situated (fig. 282) at the extremity of the elongated tentacula, and thus rendered capable of taking firm hold of the surface of a rock or other fit support. The posterior extremity of the body is, in such forms, generally provided with two broad muscular and fin-like expansions (fig. 282), evidently adapted to assist in sculling the animal along.

(1509.) Wonderful as are the provisions above described for ensuring food and safety to these formidable inhabitants of the sea, it is only by an attentive examination of the individual suckers, so numerously distributed over the tentacula, that the reader will fully appreciate the mechanism we are so inadequately describing. Machines of human construction admit of being variously estimated, as they are found to be more or less adapted to accomplish the object of the contriver; but in estimating the works of the Deity all degrees of comparison are merged in the superlative; everything is best, completest, perfect.

(1510.) Examine any one of these thousand suckers:—it is an admirably arranged pneumatic apparatus—an air-pump. The adhesive disk (fig. 281, A) is composed of a muscular membrane, its circumference being thick and fleshy, and in many species supported by a cartilaginous circlet, so that it can be applied most accurately to any foreign body. In the centre of the fleshy membrane is an aperture leading into a deep cavity (B, *b*), at the bottom of which is placed a prominent piston (*c*), that may be retracted by muscular fibres provided for the purpose. No sooner therefore is the circumference of the disk placed in close and air-tight contact with the surface of an object, than the muscular piston is strongly drawn inwards, and, a vacuum being thus produced, the adhesion of the sucker is rendered as firm as mechanism could make it.

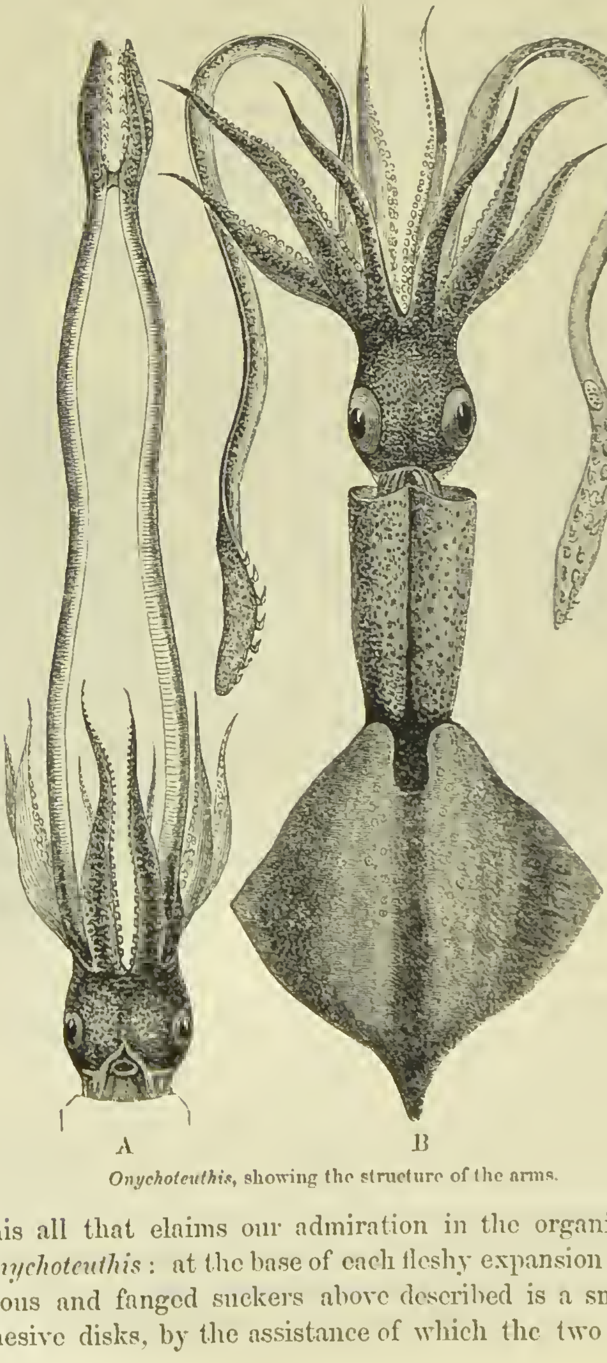
Fig. 281.



Structure of the tentacular suckers in the Cephalopoda.

(1511.) Yet even this elaborate and wonderful system of prehensile organs would seem, in some cases, to be insufficient for the purposes of nature. In the powerful and rapacious *Onychoteuthis* (fig. 282), the cupping-glasses which arm the extremities of their long pair of muscular arms are rendered still more formidable; for from the centre of each sucking-cup projects a strong and sharp hook, which is plunged by the action of the sucker deeply into the flesh of struggling or slippery prey, and thus a firm and most efficient hold upon the seized victim is secured.

Fig. 282.

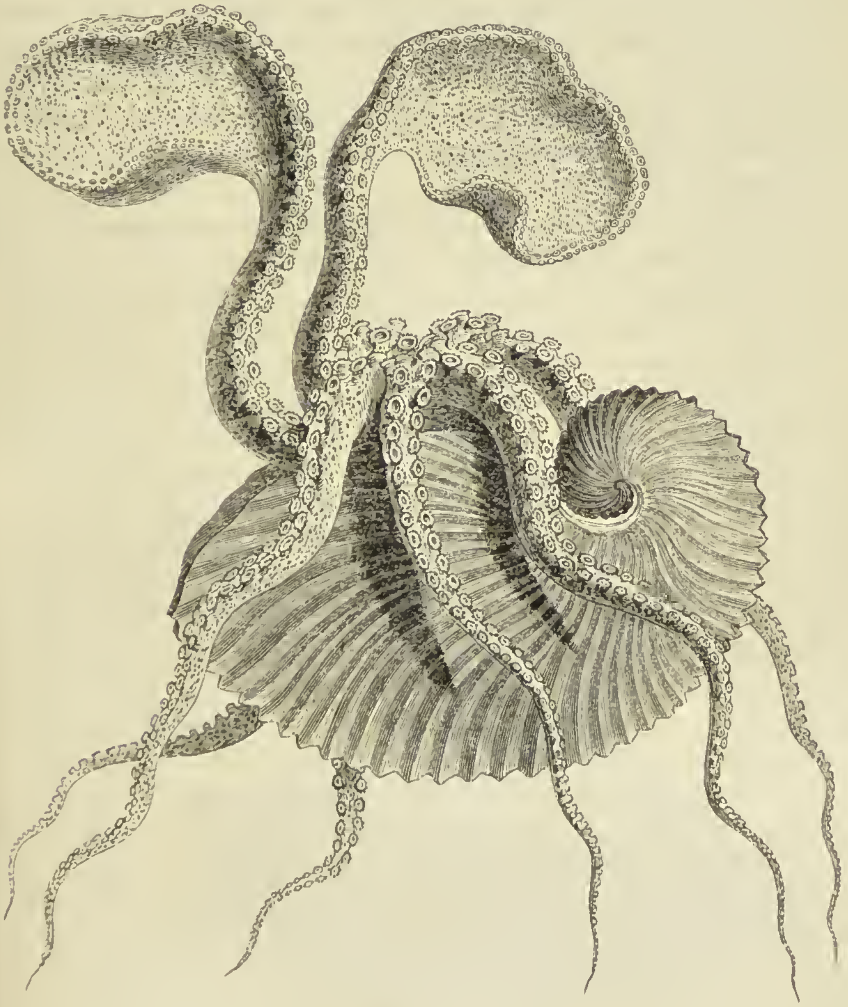


Onychoteuthis, showing the structure of the arms.

Nor is this all that claims our admiration in the organization of the arms of *Onychoteuthis*: at the base of each fleshy expansion that supports the tenacious and fanged suckers above described is a small group of single adhesive disks, by the assistance of which the two arms can be locked together (fig. 282, A), and thus be made to cooperate in dragging to the mouth such powerful or refractory prey as, singly, the arms might be unable to subdue—an arrangement which has been rudely imitated in the construction of the obstetric forceps*.

(1512.) The *Argonaut* constitutes the type of another family of the Cephalopoda, and is remarkable as being the inhabitant of a shell of exquisite beauty, familiarly known as that of the *Paper-Nautilus*—a shell which, from remote antiquity, has been decorated with all the ornaments of fiction, and celebrated alike by Poetry and her sister Arts.

Fig. 283.



Argonaut (*Argonauta Argo*). (After Poli.)

(1513.) It was, indeed, to this Cephalopod that the ancients assigned the honour of having first suggested to mankind the possibility of traversing the sea in ships; and nothing could be more elegant than the little barque in which the Argonaut was supposed to skim over the waves, hoisting a pair of sails to the breeze, and steering its course by the assistance of oars provided for the purpose.

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* Cyclopædia of Anatomy and Physiology, art. Cephalopoda.

(1514.) The figure annexed (fig. 283), given by Poli in his magnificent work already referred to*, was in perfect accordance with the generally-received opinion; and on such respectable authority we are not surprised to find Cuvier assenting to and sanctioning the statement that, when the sea is calm, fleets of these little sailors might be seen navigating its surface, employing six of their tentacula or arms instead of oars, and at the same time spreading out two, which are broadly expanded for the purpose, instead of sails. Should the waves become agitated, or danger threaten, the Argonaut, as we are told, draws in his arms, lowers his sail, and, settling to the bottom of his shell, disappears beneath the waters.

(1515.) It is a thankless office to dispel the pleasant dreams of imagination; yet such becomes our disagreeable duty upon this occasion. M. Sander Rang, in a recently-published memoir upon this subject†, has, from actual observation, apparently established the following facts: —1st, that the belief, more or less generally entertained since the time of Aristotle, respecting the skilful manœuvres of the Poulpe of the Argonaut in progressing by the help of sails and oars on the surface of the water, is erroneous. 2nd. The arms which are expanded into membranes have no other function than that of enveloping the shell in which the animal lives, and that for a determinate object to be explained hereafter. 3rd. The Poulpe, with its shell, progresses in the open sea in the same manner as other Cephalopods. And lastly, that when at the bottom of the ocean, the Argonaut, covered with its shell, creeps upon an infundibuliform disk, formed by the junction of the arms at their base, and presenting (alas!) the appearance of a Gasteropod mollusk.

(1516.) It is not a little remarkable that the same animal should, even in these days, be the subject of the extremes of credulity and scepticism; yet such has been the case with the Argonaut. While zoologists were contented to allow the creature in question the reputation of being an active and skilful navigator, it has been very generally stigmatized as a pirate, which, having forcibly possessed itself of the shell of another animal, lived therein, and made use of it for its own purposes. It was in vain to urge, in opposition to this calumny, that the Argonaut was never found in any other shell than the beautiful one represented in the preceding figure; that no other creature had been pointed out as the real fabricator of its abode; that, whatever the size of the Poulpe, it occupied a residence precisely corresponding in dimensions with those of the possessor. The apparent want of resemblance between the outward form of the animal (fig. 285) and that of its fragile covering, together with the absence of any muscular connexion between the two, were looked upon as furnishing sufficient evidence of its parasitical habits. The careful observations of Madame Jeannette Power, to be noticed more at length hereafter, and those of M. Sander Rang, above alluded to, have, however, completely settled the so long agitated question; and, the Argonaut having been watched carefully from the state in which it leaves the egg until it arrives at maturity, the manner in which it forms and repairs its frail shell is now satisfactorily understood.

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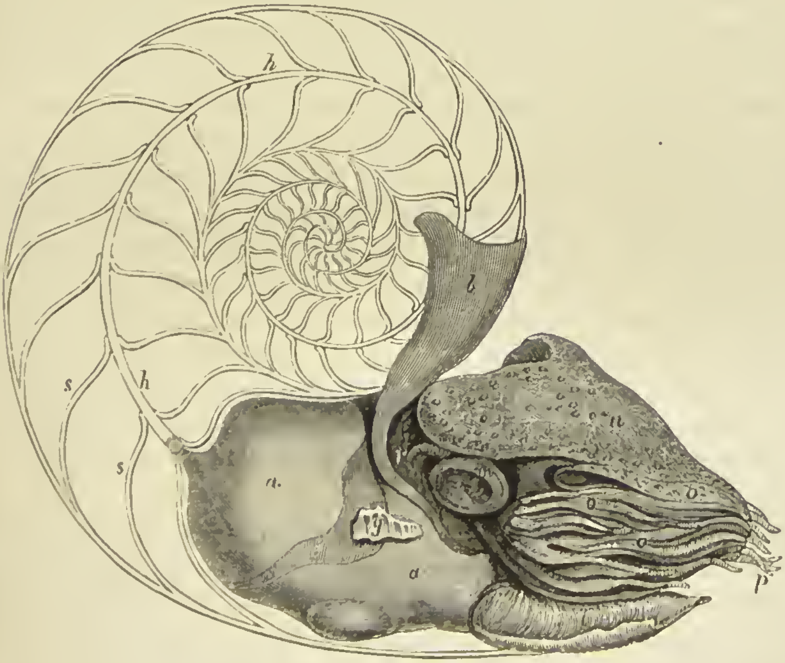
* Testacea utriusque Siciliæ.

† Guérin's 'Magasin de Zoologie.' Translated in the Magazine of Natural History, vol. iii. new series, p. 521.

(1517.) A still more interesting group of Cephalopods, and one which in former periods of the world has been extensively disseminated, inhabited chambered shells. But of all the varied forms of these creatures, whose remains are so abundantly met with in a fossil state, and known by the names of *Ammonites*, *Belemnites*, *Nummulites*, &c., two species only have been found to be at present in existence—the *Spirula*, an animal as yet imperfectly known, and the *Nautilus Pompilius*, of which the only specimen obtained in modern times* has been the

Fig. 284.



Animal of the *Nautilus Pompilius*. (After Owen.)

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* For this invaluable addition to zoological knowledge, science is indebted to George Bennett, Esq., who obtained the living animal near the island of Erromanga, New Hebrides. "It was found in Marekini Bay, floating on the surface of the water

subject of a monograph by Professor Owen, who has most completely investigated its general organization and relations with other families of the Cephalopoda. The shell of the Pearly Nautilus (*N. Pompilius*) is extremely common, and may be met with in every conchological collection, notwithstanding the extreme rarity of the mollusk that inhabits it—a circumstance, perhaps, to be explained by the fact that the living animal dwells in deep water, and when it comes to the surface is so vigilant against surprise, that at the slightest alarm it sinks to the bottom. On making a section of the shell its cavity is found to be partitioned off by numerous shelly *septa* into various chambers (fig. 284, *s s*), in the last of which the body of the animal is situated. A long tube or siphuncle (*h h*), partly calcareous and partly membranous, passes through all the compartments quite to the end of the series. The membranous siphuncle is continued into the animal, and terminates in a cavity contained within its body, hereafter to be described, which is in free communication with the exterior.

(1518.) Various conjectures have been indulged in concerning the end answered by the camerated condition of the shell in these Mollusca. Dr. Hooke* suggested the idea that the chambers might be filled with air generated by the Nautilus, and thus made so buoyant that the specific gravity of the animal and its shell should correspond with that of the surrounding medium, and that, acting in the same manner as the swimming-bladder of a fish, the creature would float or sink, as the air in its shell was alternately compressed or rarefied. Should this supposition be correct, it would seem probable, as Dr. Buckland has pointed out, that the simple retraction of the head, by injecting water from the chamber within its body (*pericardium*) into the membranous siphuncle, would cause the needful condensation of the air contained in this singular float, and allow the Nautilus to sink to the bottom; while the protrusion of its arms, by taking off the pressure, and thus allowing of the expansion of the confined air, would give every needful degree of buoyancy, even sufficient to permit the mollusk to rise like a balloon to the top of the sea.

(1519.) The body of this Cephalopod is covered with a thin mantle (*a a*), of which a large fold (*b*) is reflected on the exterior of the shell. It is securely fixed to its residence by two lateral muscles, the insertion of one of which is seen at *g*. A large coriaceous hood (*n*) covers the head, and, when the creature retreats into its habitation, closes the entrance like a door, while through the infundibulum (*i*) the ova and excrementitious matters are expelled from the body. The most re-

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not far distant from the ship, and resembling, as the sailors expressed it, a dead tortoiseshell cat in the water. It was captured, but not before the upper part of the shell had been broken by the boat-hook in the eagerness to take it, as the animal was sinking when caught."—(Dr. Bennett's Journal.)

* Philosophical Experiments and Observations. 8vo, 1726.

markable feature, however, exhibited in the external conformation of *Nautilus* is the conversion of the sucker-bearing arms of other Cephalopods into an elaborate apparatus of tentacular organs appended to the head (*o o*); but these, as well as the eye (*m*), will be more minutely described as we proceed.

(1520.) Turning our attention to the anatomical structure of the Cephalopoda, we find that in all of them the exterior of the body is entirely formed by an intricate interlacement of muscular fibres. The sac that contains the viscera, itself muscular, is united to the head by strong and largely-developed fasciculi; the funnel (fig. 285, *a*), through which, as through a fleshy pipe, the products of excretion, as well as the eggs or seminal fluid, are ejected, is formed of a tissue similarly endowed with contractility; while the arms are composed externally of muscles disposed in various directions, and moreover have their central portion occupied by strong bands, which traverse them longitudinally from end to end, so that they are thus gifted with all needful powers of motion, and may be shortened, elongated, or bent in any direction at pleasure.

(1521.) In those natatory species which, like *Loligopsis*, or *Onychoteuthis* (fig. 282), have fins appended to the sides of the visceral sac, these organs likewise are made up of muscular substance; and, being thus converted into broad moveable paddles, they also form efficient locomotive agents.

(1522.) One important circumstance observable in the class before us must not be forgotten in connexion with this portion of the history of the Cephalopods. We may remind the student that, in the vertebrate division of animated nature, to which these creatures immediately lead us, the locomotive system is supported by an internal vascular and living skeleton, composed either of cartilage, as is the case in the most imperfect vertebrated genera, or, in the more highly organized forms, of bones articulated with each other, and possessing within themselves the means of growth and renovation derived from the blood which permeates them in every part. The reader will remember that, in all the classes that have offered themselves to our notice, we have not hitherto observed anything at all comparable to an internal osseous framework such as Man possesses,—dead, extravascular shells, formed by successive depositions of layers of calcareous material, or jointed cuticular armour equally incapable of growth, having as yet represented the skeleton, and formed the only levers upon which the muscular system could act in producing the movements connected with locomotion.

(1523.) Having, however, already had abundant opportunities of seeing how gradually nature proceeds in effecting the development of a new series of organs, we might naturally be led to expect in the creatures before us some faint indications, at least, of our approach to animals possessed of an internal bony framework; and our expectations in this particular will be found on investigation to be well-grounded. It is, in fact, in the Cephalopoda, the highest of the molluscous classes, that the rudiments of an osseous system for the first time make their appearance; not, indeed, as yet composed of perfect bone, but formed of cartilaginous pieces,—some being so disposed as to protect the ganglionic mass above the œsophagus, which now from its size well deserves the name of brain, whilst others serve to afford bases of attachment to the muscular system in different regions of the body.

(1524.) The most important piece met with in the cartilaginous skeleton of the *Cuttle-fish* encloses and defends the brain, and therefore is most appropriately called the *cranial cartilage*, being the correspondent, both in position and office, with the cranium of a vertebrate animal. This rudimentary cranium embraces the œsophagus with a cartilaginous ring, encases the brain, affords passage to the optic nerves, and gives off orbital plates for the protection of the eyes. The cranial cartilage likewise gives a firm origin to the muscles of the locomotive tentacula appended to the head, and, moreover, contains within its substance an auditory apparatus, presenting the earliest condition of an organ of hearing such as is met with in the vertebrate division of the animal kingdom; in every respect, therefore, it claims to be considered as the first appearance of a *skull*. Another broad cartilage is imbedded among the muscles at the base of the funnel; and two distinct plates, situated in the lateral fins of such species as possess appendages of that description, offer, undoubtedly, the rudiments of those portions of the skeleton that sustain the locomotive limbs of quadrupeds.

(1525.) But while we thus see in the Cephalopoda the earliest form of an *internal* osseous skeleton, we cannot be surprised to find these mollusks still retaining, at the same time, the tegumentary calcareous shell or epidermic skeleton of inferior animals.

(1526.) On slitting up the mantle of a Calamary (*Loligo*) along the mesial line of the back, it is found to contain a large cavity, wherein is lodged a long plate of horn, called the *gladius*, which in shape might be not inaptly compared to the head of a Roman spear. This enclosed horny substance, notwithstanding the dissimilarity of texture, is, in fact, strictly analogous to the enclosed shell of the Slug, described in a former page; and its growth is effected in the same manner, namely by an exudation of corneous material from the floor of the chamber that contains it; and this horny secretion, hardening as it is deposited layer by layer, adds to the dimensions of the *gladius* as the growth of the animal proceeds. Several of these plates may be produced in succession; and in old individuals it is not uncommon to find two or three enclosed in the same cavity, and placed one behind the other—that nearest the visceral aspect of the chamber being the most recently formed. These rudimentary shells have no connexion whatever with the soft parts of the Calamary, to which, in fact, they are so little adherent that they fall out as soon as the sac wherein they are secreted is laid open.

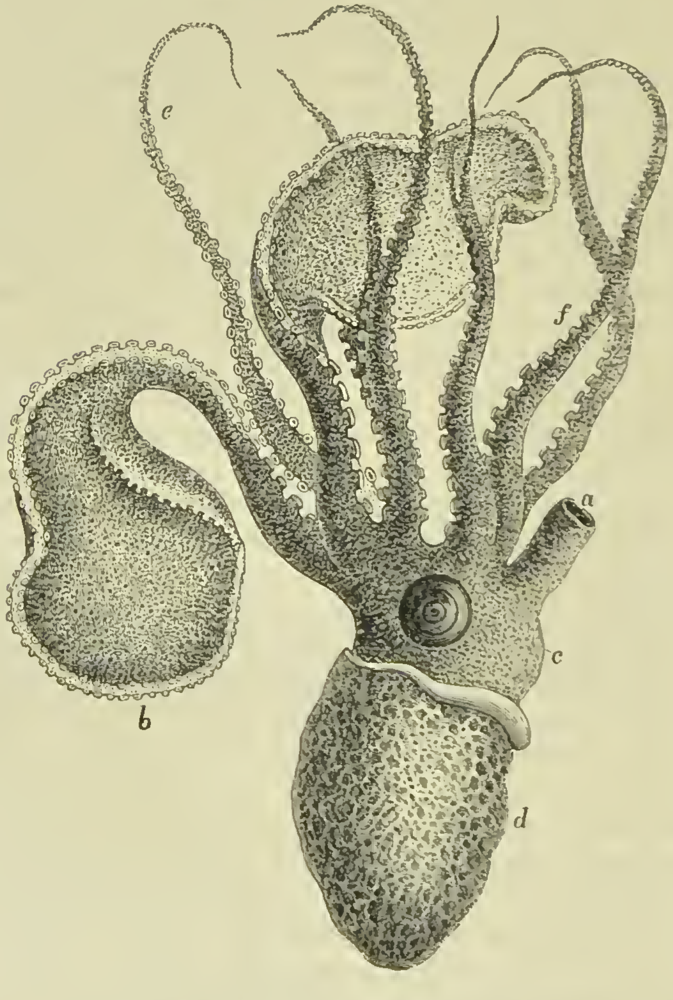
(1527.) In the Cuttle-fish (*Sepia officinalis*) the dorsal plate (*os Sepiæ*) is found in the same situation as the *gladius* of the Calamary, from which, however, it differs remarkably both in texture and composition. The *cuttle-bone*, with the appearance of which every one is familiar, is principally composed of calcareous substance, and, were we to judge of its weight from its bulk, would seem calculated materially to interfere with the movements of an aquatic animal destined to swim about, and consequently needing whatever assistance might be derived from lightness and buoyancy. Did a creature so apparently destitute of natatory organs possess a swimming-bladder like that of a fish, to assist in supporting it in the water, we should conceive such an apparatus to be far more adapted to its predatory habits than a shell so bulky as that which it is destined to carry.

(1528.) We have, however, already seen, in the case of the Nautilus, that it would be by no means impracticable to convert a shell into a float nearly equalling a swimming-bladder in efficiency; and on more accurate examination it becomes obvious that even in the bone of the Cuttle we have a provision of a similar nature, though the end arrived at is obtained in a very different manner. On making a section of a cuttle-bone, it will be found to be composed of numerous stages of very thin calcareous plates placed at some distance above each other, and kept apart by the interposition of vertical laminæ of the same substance, having, from the tortuosity of their meanderings, the appearance of millions of microscopic pillars. Thus organized, the shell in question becomes sufficiently light to float in water, and consequently, from its buoyancy, no doubt assists, instead of impeding, the movements of the mollusk. This admirable float, like the horny *gladius* of *Loligo*, is lodged in a membranous capsule and enclosed in the back of the *Sepia*, having no connexion whatever with the sides of the cavity wherein it is placed, being so loosely adherent that it readily falls out on opening the sac.

(1529.) The *cuttle-bone* is formed in the same manner as other shells, by the continued addition of calcareous laminæ secreted by that side of the containing capsule which is interposed between the shell and the abdominal viscera; and these layers, being successively added to the ventral surface of the shell, thus gradually increase its bulk as the Cuttle-fish advances to maturity. Neither in the mode of its growth nor in its texture, therefore, does the *os Sepiæ* resemble bone, properly so called; it receives neither vessels nor nerves, but is in all respects a dermal secretion, imbedded in the mantle, and formed in the same manner as the dorsal plate of the Slug.

(1530.) We now come to consider the long-disputed question relative to the nature of the shell of the *Argonaut*. The *Poulpe* that inhabits the elegant abode represented in a preceding figure (fig. 283), when removed from its testaceous covering, has the general form of an *Octopus*. Its body (fig. 285) is enclosed in an ovoid muscular sac (*d*); and the head is surmounted by eight long sucker-bearing arms, of which six (*e*, *f*) taper gradually from their origins to their extremities, while the other two, formerly regarded as sails, and which we shall continue to designate by their ordinary name, *vela*, expand into broad membranes (*b*).

Fig. 285.



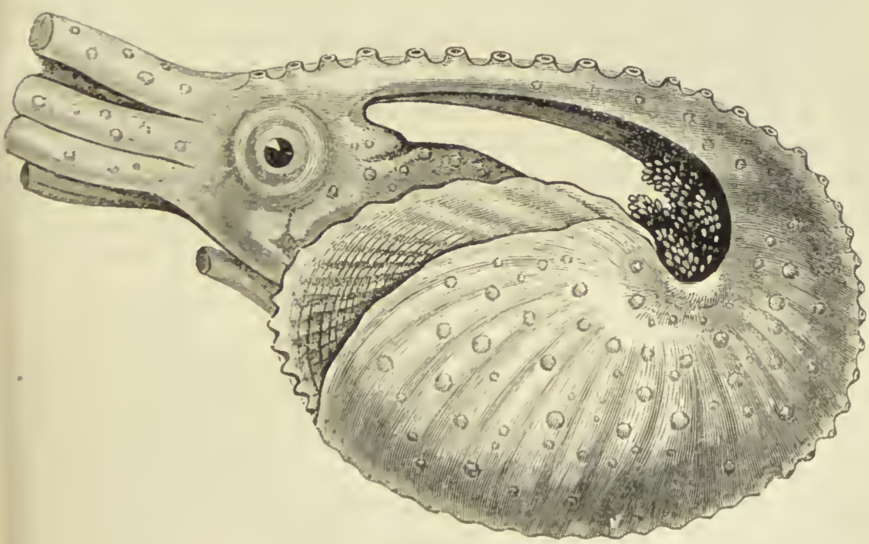
Animal of the Argonaut out of its shell: *a*, the siphon; *b*, the so-called *vela*; *c*, the head; *d*, the body; *e*, *f*, locomotive tentacula. (After Poli.)

(1531.) M. Sander Rang, who, during a residence at Algiers, had ample opportunity of studying the living Argonaut, ascertained that in the figure copied from Poli, which we have given in a preceding page.

the animal is placed in its shell in a reversed position, and that, when alive, the creature is always found with its veliferous arms turned towards the spire of its shell, instead of in the opposite direction, as represented in the drawing referred to. Moreover, the *vela*, instead of forming sails, are invariably tightly spread out over the external surface of the shell (fig. 286), which they cover and entirely conceal from view. With its veliferous arms thus firmly embracing its abode, the Argonaut has two modes of progression. It can certainly raise itself from the bottom, and sport about at the surface of the water; but this is simply effected by the ordinary means used by Calamaries and Cephalopods in general, namely by admitting the sea-water into its body and then ejecting it in forcible streams from its funnel, so as to produce a retrograde motion, which is sometimes very rapid. Its usual movements are, however, confined to crawling at the bottom with its head downwards; and in this way it creeps, carrying its shell upon its back.

(1532.) The reader will obtain a better idea of the real appearance of the Argonaut in its shell by inspecting the annexed copy of M. Rang's figure than from any verbal description, and we borrow that gentleman's own account of its general appearance*. The membranous portions of the expanded arms, dilated beyond anything we could have pictured to ourselves while knowing the animal merely by specimens preserved in spirits of wine, are spread over the two lateral surfaces of the shell in such a manner as to cover it completely from the base of the hard edge to the anterior extremity of the edge of the opening,

Fig. 286.



Argonaut. (After M. Sander Rang.)

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* For more ample details upon this subject, the reader is referred to an excellent translation of M. Rang's paper contained in Mr. Charlesworth's Magazine of Natural History, new series, vol. iii.

and consequently the keel. The application of these membranes is direct, and without any puckering or irregularity whatever,—the lower part of the two large arms being completely stretched, so as to form a kind of bridge over the cavity left between the back of the mollusk and the retreating portion of the spire. When the mollusk contracts itself, it frequently draws in more or less completely its large arms and their membranes, so as partially to uncover the shell in front, as is represented in the figure (fig. 286).

(1533.) There is little doubt that the *vela* of the Argonaut, which thus envelope its abode, are the organs employed in constructing the brittle fabrics, and the agents whereby fracture and wounds in the shell are repaired and filled up.

(1534.) The positive experiments of Madame Power* leave no doubt upon the subject; for not only did that lady, by rearing young Argonauts from the egg, watch the first appearance and earliest growth of the shell, but, by breaking the testaceous covering of adult specimens, she found that they could readily repair the damage inflicted. Being desirous of observing the manner in which this operation was accomplished, the lady to whom science is indebted for these interesting researches examined an individual on the day after its shell had been intentionally broken, and found that the aperture was already covered by a thin glutinous lamella, which, although as yet as delicate as a cobweb, united the margins of the fracture. The next day the lamella had become thickened to a certain degree and more opake; till at length, at the end of ten or twelve days, the new piece had become quite calcareous. Madame Power is likewise certain that, while in the act of mending the fractures, the Argonaut applied its *vela* to the exterior of the shell, and wrinkled them upon it; whence they may naturally be regarded as being the source from which the glutinous secretion that finally became hardened into shell proceeded.

(1535.) In order to understand the manner in which the remarkably-constructed camerated shells, such as those of *Nautilus*, are produced, it is not necessary to imagine any deviation from the simple mode of procedure adopted in all the cases we have as yet considered. The continual elongation of the spiral cone is, as is evident from the lines of growth visible upon its outer surface, effected by the addition of successive layers to the margin of the aperture of the last-formed chamber, wherein the animal resides; and as the production of the calcareous secretion whereby the shell is enlarged is most rapidly effected upon that side of the body where the funnel (fig. 284, *i*) is situated, the gradually-expanding shell naturally revolves around an excentric axis. While the growth of the shell continues, the animal is constantly advancing forwards, and thus leaves the first-formed portions of the shell unoccupied. At intervals, as the Nautilus thus removes itself further and further from the bottom of its abode, that portion of its mantle which covers the general surface of its visceral sac (fig. 284, *a*) secretes floors of shelly substance behind it; and thus the septa (*s s*) are formed, whereby the shell is separated into chambers, every chamber having in turn been occupied by the body of the Nautilus. The gradual prolongation of the fleshy siphon (*h*) is easily understood, because it naturally increases in length with the growth of the animal: but how the two muscles (fig. 284, *g*), that fix the body to the shell, progressively advance their points of attachment as the shell enlarges, is not so readily explained; neither are we prepared to account satisfactorily for the accomplishment of this part of the process.

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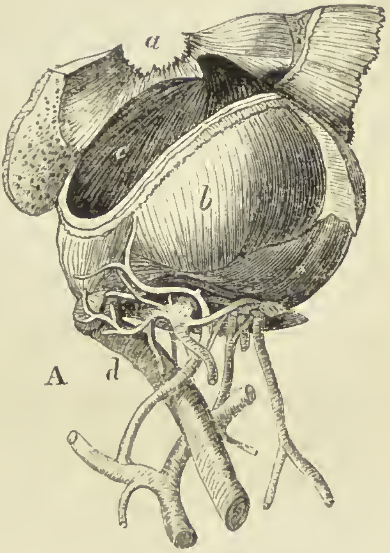
* Magazine of Natural History, April 1839, "Observations on the Poulpe of the Argonaut," by Madame Jeannette Power.

Fig. 287.



Jaws of the Cuttle-fish. A: *a*, fleshy orifice of the mouth; *b*, muscular mass of the mouth; *c*, mandibles; *d*, œsophagus. B, horny beak of the Cuttle-fish, in outline.

(1536.) It has been already stated that in all Cephalopods the aperture of the mouth is situated in the centre of the disk formed by the union of the origins of the feet (figs. 282, 289). The oral orifice is generally surrounded by a broad circular lip (fig. 287, A, *a*), which being not unfrequently fringed or papillose, there is little doubt of its possessing sufficient sensibility to render it of material assistance in manducation.

(1537.) The circular lip partially conceals a pair of strong horny mandibles, not unlike the beak of a parrot, but differing in this particular, that in the Cephalopod the upper mandible is the shorter of the two, and is overlapped by the lower jaw. The mandibles detached from the soft part are represented in fig. 287, B, *a*, *b*). There is likewise another important difference between the structure of the beak of the Cuttle-fish and that of the Bird, inasmuch as in the former there is no bony support to the horny jaws, and consequently some other means of sustaining them must be had recourse to. We accordingly find the place of the jaw-bones supplied by a fibro-cartilaginous substance (fig. 288, *c*) that fills the interior of each mandible, and thus gives it sufficient solidity for all required purposes.

Externally the jaws are imbedded to a considerable depth in a strong mass of muscle (fig. 287, *b*), composed of several layers of fibres variously disposed, so as to open or close the jaws with a degree of force proportioned to their large size. Here therefore is an apparatus fully adequate to cooperate with the elaborately-constructed prehensile arms whereby these predatory animals seize their prey; and a victim once involved in the tenacious grasp of the tentacula, and dragged to this powerful beak, can have but little chance of resisting means of destruction so formidable as those granted to the Cephalopoda.

(1538.) The mandibles of *Nautilus Pompilius*, instead of being entirely composed of horn (as is invariably the case in those genera that, being provided with tentacula armed with suckers, are thus capable of seizing active and slippery animals), would seem to be rather calculated to break to pieces the testaceous coverings of Mollusca or the armour of the Crustacea. They possess, indeed, the shape of the jaws already described, but are blunt at their extremities (fig. 289, *n*, *o*), and thickened by a covering of a dense calcareous substance; so that they appear manifestly adapted to crush hard substances rather than to cut or lacerate the tender bodies of fishes*. The jaws of the Nautilus, like those of the Octopus above described, are imbedded in a powerful mass of muscles (*p*) whereby they are opened and shut with great force, and are also provided with a distinct muscular apparatus destined to protrude them when in use, and again to retract the whole mass of the mouth deeply into the body when unemployed. The mechanism provided for the protrusion of the mandibles is a strong semicircular muscle (*r r*), which firmly embraces the base of the oral apparatus, and by its contraction pushes it outwards among the labial tentacula (*h*. *k*); while, on the other hand, four retractor muscles, the upper pair of which are represented in the figure referred to (*q q*), arise from the extremities of the cranial cartilage, and, running forwards to be inserted into the oral mass, are the agents whereby the whole is again withdrawn and thus concealed from view.

(1539.) The tongue of the Cephalopoda, as in the Mollusca described in the last two chapters, is an exceedingly important instrument, and from its construction would here seem to be an organ of taste, as well as a necessary assistant in deglutition. In the annexed figure, representing a vertical section of the beak of a very large *Onychoteuthis*, the shape and disposition of the different parts of the tongue are well seen. The substance of the tongue itself is fleshy (fig. 288, *e*, *i*), and its movements are principally performed by the action of its own intrinsic muscular fibres: its surface is divided into several lobes (*f*, *g*, *h*), partially invested with a delicate and papillose membrane; but a large portion of the organ is covered with sharp recurved horny hooklets, so disposed that with their assistance the morsels of food taken into the mouth are seized and dragged backwards, by a kind of peristaltic motion, to the commencement of the œsophagus (l). The necessity of the provision thus made for enabling the Cephalopods to swallow the substances upon which they feed must be at once apparent; for, seeing that the walls of the mouth are formed entirely by the hard and inflexible horny beak, it is difficult to conceive how deglutition could have been accomplished by any other contrivance.

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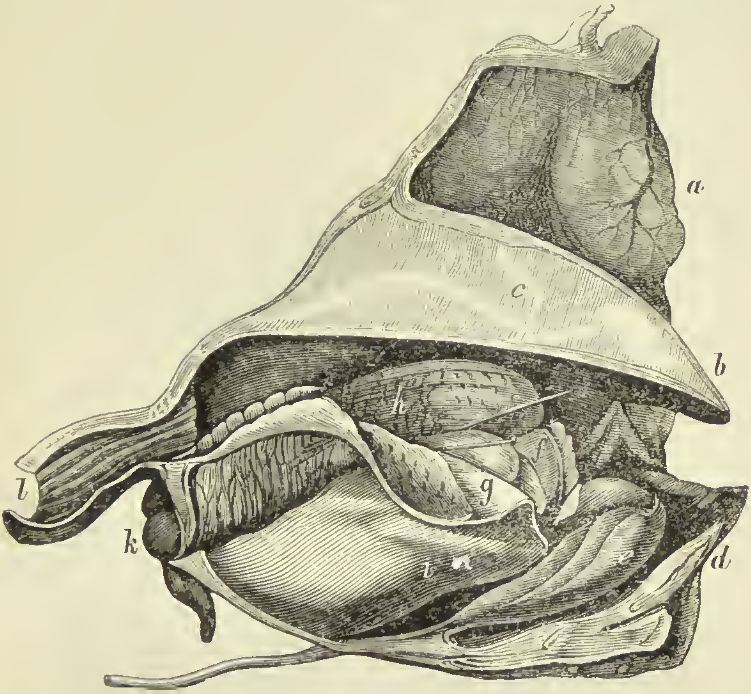
* Owen, 'Memoir on the Pearly Nautilus.' London, 1832, 4to.

Fig. 288.

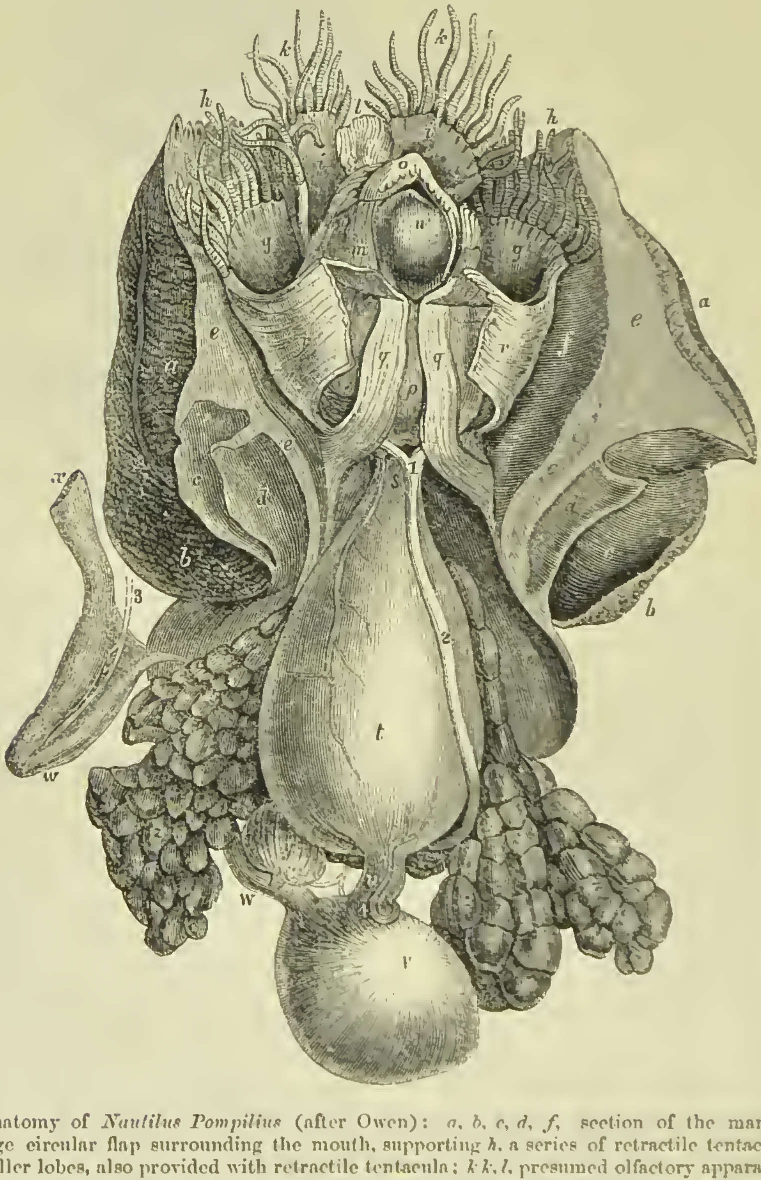


Section of the oral apparatus of *Onychoteuthis*: *a*, circular lip surrounding the mouth; *b*, *d*, horny beak; *c*, cartilaginous substance forming the bulk of the mandible; *e*, *i*, muscular tongue; *f*, *g*, *h*, lobes upon its surface; *k*, salivary glands; *l*, œsophagus.

(1540.) Four salivary glands pour a copious supply of saliva into the oral chamber: of these, two, situated on the sides of the root of the tongue, give off distinct ducts, which terminate near the commencement of the œsophagus; while the other pair, generally larger than the superior, are lodged in the visceral sac on each side of the upper part of the crop. The inferior salivary glands each furnish an excretory canal; but their two ducts soon unite into a single tube which, with the œsophagus, passes through the ring formed by the cranial cartilage, and, piercing the fleshy mass of the mouth, opens in the neighbourhood of the spiny portion of the tongue, so that the secretion furnished at this point serves to moisten the aliment as it is taken up by the lingual hooks to be swallowed. In *Onychoteuthis* two salivary glands (fig. 288, k) are situated at the root of the tongue; and their ducts are pointed out in the drawing by pins introduced into their orifices.

(1541.) The alimentary canal presents the same general structure in all the Cephalopod families. The œsophagus (fig. 287, A, *d*; fig. 289, *s*), derived from the posterior part of the fleshy mass of the mouth, passes through a ring formed in the cranial cartilage; or else, as in *Nautilus*, is partially embraced by processes derived therefrom. It soon dilates into a capacious crop (fig. 289, *t*), the walls of which are glandular; and being lined with a mucous membrane that is gathered into longitudinal plicæ, this organ readily admits of considerable dilatation.

Fig. 289.



Anatomy of *Nautilus Pompilius* (after Owen): *a*, *b*, *c*, *d*, *f*, section of the mantle: *g*, large circular flap surrounding the mouth, supporting *h*, a series of retractile tentacula: *i*, smaller lobes, also provided with retractile tentacula; *k k*, *l*, presumed olfactory apparatus. *m*, circular lip; *n*, *o*, horny mandibles; *p*, *q*, *r*, muscular apparatus of the mouth: *s*, œsophagus; *t*, crop; *v*, gizzard; *w w*, intestine; *x*, anus; *y*, pancreatic organ; *z z*, lobes of the liver.

(1542.) From the crop, a short passage (fig. 289, *u*) leads into a strong muscular gizzard (*v*) resembling that of a granivorous bird, and lined in the same manner by a thick coriaceous cuticular layer: in this gizzard, therefore, the food is gradually bruised and reduced to a pultaceous magma.

(1543.) At a little distance from the gizzard there is, in the Nautilus, appended to the side of the intestine, a globular viscus (*y*), which is hollow, and its cavity communicates freely with the intestinal canal. The interior of this organ Professor Owen found to be occupied by broad parallel laminæ, puckered transversely, so as to offer a great extent of surface; and when examined under a lens, their structure was seen to be follicular, and evidently fitted for secretion. The bile is poured into this cavity, at the extremity furthest from the intestine, by a duct large enough to admit a common probe.

(1544.) In other genera this laminated viscus is represented by a cæcal appendage to the intestine, placed precisely in the same situation; and on opening it, its internal surface is found to be increased by a spiral lamella that winds closely upon itself from one end to the other. In such cases it is near the apex of the spire that the bile is received from the liver; so that in all essential particulars this spiriform viscus is precisely analogous to the laminated cavity of the Nautilus. There can be little doubt that this apparatus represents a capacious duodenum, and that it is by the extensive surface afforded in its interior that the nutritious portions of the food are separated, as neither the gizzard nor the intestine itself presents an organization adapted to such a purpose. With respect to its other uses Professor Owen remarks that its reception of the biliary secretion renders it in some measure analogous to a gall-bladder; but most probably its chief office is to pour into the commencement of the intestinal canal a fluid which is necessary for the completion of digestion; so that, like the pyloric appendages of fishes, it might be considered to be the representative of a *pancreas*.

(1545.) The remainder of the intestine is a simple tube, which, after one or two turns upon itself, mounts up to the base of the funnel, into which it opens, and thus allows the excrement to be ejected to a distance from the body.

(1546.) The liver (fig. 289, *z*) is of very great bulk when compared with the rest of the digestive apparatus. In *Nautilus* it is divided into four distinct lobes, which are themselves made up of numerous lobules of an angular form, each being invested with a very delicate capsule. On removing the capsule every lobule is seen to be composed of numerous acini, which with a needle may be readily separated into clusters connected by the ramifications of their excretory duct. In other genera, such as *Octopus*, wherein these acini have been minutely examined, they have proved to be delicate cells or secerning cæca wherein the bile is elaborated. The excretory canals derived from all the lobules of the liver unite by repeated anastomoses, and thus form two main trunks, which ultimately join, and pour the biliary secretion into the laminated or pancreatic cavity (y).

(1547.) In the Cephalopods, as in all the Mollusca, the bile is separated from arterial blood supplied by large vessels derived immediately from the aorta,—no system of veins analogous to the *vena portæ* of higher animals being as yet developed.

(1548.) In the Dibranchiate genera the liver is either undivided, or presents only two lobes; but in other respects its composition and minute structure is similar to that of the Nautilus.

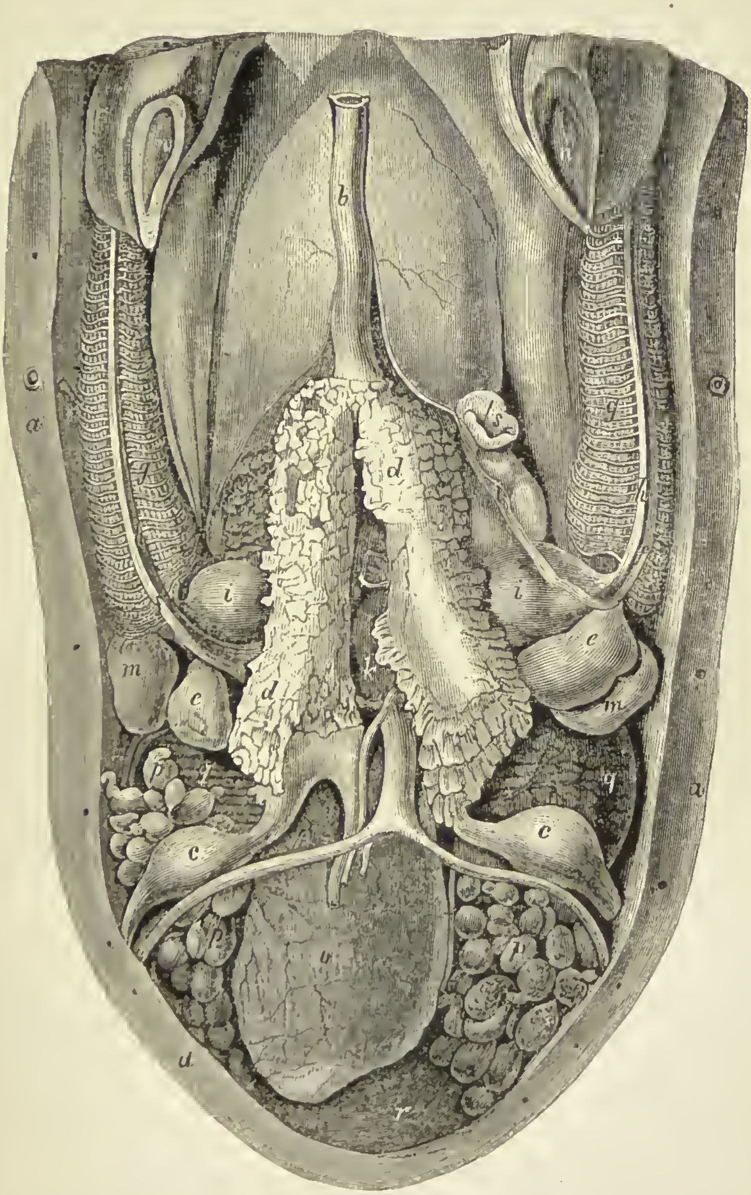
(1549.) In all the CEPHALOPODA, with the exception of the *Nautilus Pompilius,* there is an orifice in the immediate vicinity of the anus, through which a coloured secretion, generally of a deep-brown or intense-black colour, can be poured in astonishing abundance; and this becoming rapidly diffused through the surrounding water, a means of defence is thus provided; for no sooner does danger threaten, or a foe appear in the vicinity of the Cuttle-fish, than this ink is copiously ejected, and the element around rendered so opake and cloudy, that the Cephalopod remains completely concealed from its pursuer, and not unfrequently ensures its escape by this simple artifice. The organ wherein the inky secretion is elaborated is a capacious pouch, variously situated in different genera. In *Octopus* it is enclosed in the mass of the liver; in *Loligo* it is located in the immediate vicinity of the anus; and in *Sepia* (fig. 290, q) the ink-bag is lodged near the bottom of the visceral sac. On opening it, and carefully washing away by copious ablution the ink within, the cavity of the ink-bag is seen to be filled up with a spongy cellulosity, wherein the blacking material had been entangled: and from this cellular chamber a duct leads to the outward orifice, through which the dark secretion is ejected at the will of the animal, and squirted from the extremity of the funnel.

(1550.) The CEPHALOPODA breathe by means of branchiæ, and possess a complex and elaborate circulatory system, organized upon very extraordinary principles, to tho consideration of which we now invite the attention of the reader.

(1551.) The branchiæ (fig. 290, $g\,g$) in all the genera now known to exist, with the exception of the *Nautilus,* are two in number, one situated on each side of the body; but in the *Nautilus Pompilius* there are four branchial organs, two on each side; and hence Professor Owen has divided the class into two great orders, under the names of *Dibranchiata* and *Tetrabranchiata,*—the former embracing all the ordinary genera, while the latter is, as far as we know, only represented in modern times by the Pearly Nautilus, depicted in a preceding figure.

(1552.) In both the *Dibranchiate* and *Tetrabranchiate* orders, each branchia consists of a broad central stem, to which is appended a series of vascular lamellæ, seen in the figure given below (fig. 290, g): by this arrangement a very extensive surface is obtained, over which the blood is diffused for the purpose of respiration. The respiratory apparatus is lodged within the visceral sac, but separated from the other viscera by

Fig. 290.



Anatomy of the Cuttle-fish (after Hunter): *a a*, section of the mantle; *b*, *c*, venæ cavæ; *d*, spongoid appendages of ditto; *e c*, branchial hearts; *m m*, their lateral appendages; *f f*, ligaments of branchiæ; *g*, branchial organs; *h*, branchial vein; *i i*, systemic auricles; *k*, systemic ventricle; *o*, the stomach; *p*, *q*, the ovaria.

a membranous septum (fig. 289, *t*); so that a distinct chamber is formed to contain the branchiæ, into which the water is freely admitted,—the surrounding element being alternately drawn into the branchial cavity, by the action of its muscular walls, through a valvular aperture provided for the purpose, and again expelled in powerful streams through the orifice of the funnel. Such, indeed, is the force with which the water is ejaculated through the funnel, that it not only serves to expel from the body excrementitious matter derived from the termination of the rectum (fig. 290, *s*), which opens into the respiratory cavity, but becomes one of the ordinary agents in locomotion. This mode of progression, although in fact common to most of the Cephalopod tribes, is remarkably exemplified in the Argonaut, which, instead of navigating the surface of the sea, as has been already stated, simply darts itself from place to place by sudden and oft-repeated jets thus violently spouted forth, while with its arms stretched out and closely approximated, and its vela tightly expanded over the outward surface of its delicate shell, it shoots backwards like an arrow through the water.

(1553.) Separated from the chamber in which the branchiæ are lodged, by the membranous partition already mentioned (fig. 290, *t*), and likewise distinct from the peritoneum containing the viscera, is a considerable cavity, divided by a membranous partition into two compartments, wherein are placed the great trunks of the venous system (*d d*). These chambers, named by Cuvier* the "great venous cavities," are very remarkable, inasmuch as, although they contain the *venæ cavæ*, which here present a truly anomalous structure, they are lined with a mucous membrane derived from the branchial chamber, with which they are in free communication, and from whence the external element has free admission to their interior.

(1554.) It is in this "*great venous cavity*," called by Professor Owen the "*pericardium*," that, in the Pearly Nautilus, the siphon which traverses the partitions of its camerated shell (fig. 284) terminates; and the reader will now perceive by what mechanism water received from the branchial chamber may, in that animal, be injected into its partitioned shell for the purpose already referred to (§ 1517).

(1555.) In the "*great venous cavity*," or "*pericardium*," thus formed, are lodged the principal venous trunks (fig. 290, *d d*), into which the blood derived from all parts of the body is brought by capacious vessels (*b*, *c c*) that may be called the *venæ cavæ*. The great central receptacles of the venous blood (*d d*), whilst they are contained in the *pericardium* (or, rather, project into its interior, being partially covered with the mucous membrane that lines its walls), are enveloped by a mass of spongy appendages of a most remarkable and peculiar description. These spongy masses are of a yellow colour, and, when squeezed, they give out an opake yellowish mucosity†; but the most interesting circumstance connected with these bodies is, that they communicate by large and patulous apertures with the interior of the veins to which they are adherent. The short canals derived from these apertures are themselves pierced by very numerous orifices, and so on successively, until each of the spongy bodies referred to is permeated internally by a multitude of short vessels leading one into another, and ultimately into the vein itself. Cuvier supposes that, seeing it is impossible that these vessels should not be filled with blood, they might themselves be considered as veins; but then their extent, when compared with tho very small arterios of the spongy bodies, forbids us to believe that they have no other office than that of bringing back into the general current of the venous circulation blood derived from these arterial ramifications. He suggests, therefore, that they more probably form diverticula in which the venous blood may become diffused, in order to receive, through the intervention of their spongy walls, the influence of the surrounding medium; so that in this way they may be subservient to respiration; or else it is possible that the orifices in the veins are the openings of excretory canals derived from these appendages, through which they may pour into the vein some substance derived from the water in which they float. Lastly, it is conjectured that they may be emunctories, through which some principle separated from the blood is discharged from the body through the pores upon their surface—a supposition rendered more probable, seeing the abundant mucous secretion that may be extracted from them by pressure. "However this may be," observes Cuvier, "it is certain that the communication between these bodies and the exterior is very open; for on blowing into or injecting the vein, the air or injection passes very readily into the cavity that the vein traverses; and, on the other hand, on inflating the cavity from the branchial chamber, it often happens that the vein becomes filled with air."

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* Mémoire sur la Poulpe.

† *Ibid.*

(1556.) Mayer* not only adopts the last of the above-mentioned suggestions relative to the nature of these spongy appendages to the great veins of the CEPHALOPODA, but ventures to bring forward an opinion that they perform the office of the kidneys of higher animals, and separate from the blood a fluid analogous to the urinary secretion; so that, according to this view, the anatomist referred to does not scruple to designate the chamber called by Professor Owen the "*pericardium*" as a urinary bladder; and to the two orifices leading from thence to the cavity in which the branchiæ are lodged he would assign the name of *urethræ*. Professor Owen has suggested that, in addition to their subserviency to secretion, these appendages to the veins of Cephalopods may be provisions for enabling their sanguiferous system to accommodate itself to those vicissitudes of pressure to which it must be constantly subjected, and that they bear a relation to the power possessed by these animals of descending to great depths in the ocean,—thus answering the same purpose as the capacious auricle and the large venous sinuses that terminate in the heart of fishes. According to this view, these follicles relieve the vascular system by affording a temporary receptacle for the blood whenever it accumulates in the vessels, owing to a partial impediment to its course through the respiratory organs, serving in this manner to regulate the quantity of blood sent to the branchiæ*.

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* Analecten für vergleichenden Anatomie. 4to, 1835.

(1557.) In *Nautilus*, Professor Owen found, in addition to the spongoid appendages connected with the veins, lodged in what he denominates the "*pericardium*," that the great trunk of the *vena cava* itself presents a structure precisely analogous to what has been already described when speaking of the venous system of *Aplysia* among the GASTEROPODA (§ 1420), namely a free communication between the interior of the vein and the cavity of the peritoneum†. The vein is of a flattened form, being included between a strong membrane on the lower or ventral aspect, and a layer of transverse muscular fibres which decussate each other on the upper or dorsal aspect. The adhesion of the coats of the vein to the muscular fibres is very strong; and these fibres form in consequence part of the parietes of the vein itself throughout its whole course. But there are several small intervals left between the muscular fasciculi and corresponding round apertures both in the vein and in the peritoneum; so that the latter membrane at these points seems to be continuous with the lining membrane of the *vena cava*. The distinguished anatomist referred to counted as many as fifteen of these openings, and most of them were sufficiently large to admit the head of an eye-probe. Here, therefore, as in *Aplysia*, there are direct communications between the interior of the *vena cava* and the great serous cavity of the abdomen; and moreover, in both instances, from the peculiar muscular structure of the vein at the part where these orifices occur, their use appears to depend on, or to be in connexion with, a power of regulating their diameters‡.

(1558.) The blood derived from the great venous receptacles (fig. 290, *d d*) is at once conveyed to the branchiæ, and distributed through all the lamellæ (*g g*) which enter into the composition of the respiratory apparatus. Two distinct hearts, one placed on each side of the body, are interposed between the branchiæ and the great trunks of the venous system, serving by their action forcibly to drive the blood through the ramifications of the branchial arteries. These lateral hearts (fig. 290, *e e*) are of a blackish colour, and their walls moderately thick: internally their cavities are filled with intercommunicating cells; and moreover a strong mitral valve is placed at the orifice through which they receive blood from the veins, as well as smaller valvules at the origin of the branchial arteries; the latter enter the principal stem of the branchiæ, and, running beneath the ligament (*f*), divide and subdivide, so as to be dispersed over all the branchial leaflets.

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* Memoir on *Nautilus Pompilius*, p. 34.

† *Op. cit.*

‡ *Op. cit.* p. 30.

(1559.) In *Sepia* there is appended to each lateral heart a fleshy appendage (*m m*), which, however, is not met with in the generality of Dibranchiate Cephalopods. These bodies are attached to the hearts by narrow pedicles; and Professor Owen considers them to be rudiments of the additional pair of branchiæ met with in the Pearly Nautilus.

(1560.) In *Nautilus Pompilius* the hearts just mentioned do not exist, doubtless because the greater extent of surface afforded by the four branchiæ of this Cephalopod renders the presence of extraordinary agents for impelling the blood through them, in order to ensure efficient respiration, unnecessary.

(1561.) After undergoing exposure to the surrounding medium in the extensive ramifications of the branchial arteries, the purified blood is returned to the organs belonging to the systemic circulation. In *Sepia* it is first received from the branchiæ by two dilated sinuses (*i i*), which might almost be regarded as systemic auricles; and from these it passes into a strong muscular cavity (*k*), which corresponds in function with the left ventricle of the human heart, and by its pulsations forcibly propels the blood through all the arterial ramifications of the vascular system. Two aortæ, one derived from each of its extremities, arise from the systemic ventricle, the commencement of each being guarded by strong valves so disposed as to prevent all reflux towards this central heart; and thus the circuit of the blood, accomplished in this complicated system of blood-vessels, is completed. In *Nautilus* the lateral sinuses are wanting, and the systemic ventricle is of a square shape; but in other respects the course of the circulation is the same as is above described.

(1562.) In the Poulpe (*Octopus vulgaris*)*, the blood thus distributed through all parts of the body by the arterial vessels returns towards the branchiæ through a system of venous canals composed partly of vessels furnished with distinct parietes, partly of a series of lacunæ or spaces only circumscribed by the circumjacent parts.

(1563.) The veins derived from the anus and the cephalic region, in conjunction with those of the siphuncle and the great visceral veins, at length unite and form by their union the two venæ cavæ (fig. 290, *d d*), through the intervention of which the greater part of the blood is conducted to the preliminary hearts (fig. 290, *e e*). So far these venous trunks offer no very striking peculiarity, but arrived in the vicinity of the gizzard they present a very remarkable arrangement: instead of being formed by the junction of other smaller veins, they become uninterruptedly continuous, with an immense venous reservoir which occupies all the dorsal aspect of the abdomen, and, indeed, they seem to be a continuation of this membranous reservoir. It is to M. Delle Chiaje† that the merit belongs of having first indicated the existence of this curious arrangement; but while the illustrious Neapolitan naturalist regards it as being simply a large venous sinus, Milne-Edwards looks upon it as being the visceral cavity itself, lined with peritoneum, as in the higher animals, into which the blood is received, and wherein it bathes directly the pharyngeal mass, the salivary glands, the stomachs, and the other principal viscera. In the Cuttle-fish (*Sepia*) and in the Calamary (*Loligo*), the above peculiarities met with in the "Poulpe" do not exist, so that there is a remarkable accordance between the internal structure of these Cephalopods and the zoological characters furnished by the number of their cephalic appendages. In those genera furnished with only four pairs of arms the venous system is semilacunose in its character, whilst in the ten-armed races it is entirely vascular throughout the abdomen, although it still presents a lacunose character in the cephalic region.

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* Milne-Edwards, Ann. des Sci. Nat. 1845, tom. iii. p. 346.

† Istituzioni di Anatomia e Fisiologia Comparata, parte 1ª, Animali senza Vertebre del Regno di Napoli, tom. i.

(1564.) In the nervous system of the CEPHALOPODA we may naturally expect to find not only a superiority in the development of the nervous centres, as compared with the condition of these important masses in the lower Mollusca, but some indications at least of an approximation to that arrangement so eminently characteristic of the vertebrate division of the animal world, to the confines of which we are now gradually approaching; more especially as, in the activity of the movements of these creatures, and in the increased perfection of their senses, we have abundant evidence of the elevated position assigned to them when contrasted with other mollusks of less carnivorous and rapacious habits.

(1565.) The nervous ganglia from whence the muscles and viscera derive their supply are still numerous and widely scattered; but their size is considerable, and proportioned to the importance of the organs over which they preside. It is to the encephalic portions of the nervous system, however, that we must principally turn our attention if we would rightly estimate this part of their economy; and these, we at once perceive, have in the class before us attained to such magnitude and importance that they emulate, no longer dubiously, the brain of a fish, with which it is not difficult to compare them.

(1566.) In a Cephalopod the *encephalon* (for so we now may truly call it) is enclosed, as has been already noticed, in a distinct cartilaginous skull, which embraces it on all sides and defends it from injury. The capacity of the cranial cavity, however, is more than sufficient to contain the brain; and, as is the case in fishes, the interspace is filled up with a semigelatinous substance. The brain, moreover, still forms a ring, through which tho œsophagus passes; so that we might with propriety preserve the terms supraœsophageal and infraœsophageal ganglia, were these parts not now become so intimately united to each other that they seem fused into a single mass (fig. 294, *a*, *b*), from different portions of which, nerves serving very different offices take their origin.

(1567.) In *Nautilus* the nervous system has been most minutely and critically examined; and the important deductions to which the researches of Professor Owen point, relative to the analogies that may be traced between the encephalon of these creatures and the brain of higher animals, have served to attach an interest to the study of this part of the economy of the CEPHALOPODA which has scarcely as yet been sufficiently appreciated by physiologists.

(1568.) In the *Nautilus Pompilius*, the supra-œsophageal ganglion of the GASTEROPODA is represented by a thick round cord of nervous matter (fig. 291, 1), which is in communication with two nervous collars (3 3, 4 4) that surround the œsophagus, and likewise with two large ganglia (2) from which the optic nerves take their origin; but in the Cuttle-fish the same portion of the nervous system (fig. 294, *a*) is much more largely developed, and presents a ganglionic mass of considerable size. If we inquire the reason of this want of correspondence in magnitude presented by the same organ in these two cases, we must necessarily examine the relations in which this part of the brain stands with other circumstances in the economy of the two animals in question; and we perceive, as Professor Owen has most satisfactorily demonstrated*, that the brain is here developed in accordance with the relative complexity of the organ of vision, and also with the perfection of the locomotive faculties possessed by the Cephalopods under consideration. With the exception of sundry small twigs given off to the mouth and pharynx, the optic nerves (fig. 291, 2; fig. 294, *e*) are the only ones derived from this part of the encephalon; and, as we shall afterwards see, both the simply-constructed eye of the *Nautilus* and the complicated visual organs of the *Sepia* are correspondent to the development of the supra-œsophageal brain; so that consequently the latter may, with every show of reason, be looked upon as the representative of the optic lobes found in the encephalon of fishes†, and the analogue of the bigeminal bodies in the brains of the higher Vertebrata.

(1569.) The ganglia connected with the inferior aspect of the supra-œsophageal mass form two distinct collars embracing the œsophagus,—an arrangement of which we have already met with an example in *Clio borealis* among the Pteropod Mollusca. In *Nautilus*, the anterior ring of nervous substance, which no doubt ought rather to be considered as an agglomeration of ganglia than as a simple ganglionic mass, gives off nerves, 1st, to the ophthalmic tentacles (fig. 291, 5); 2ndly, to the digital tentacles (6); 3rdly, there arises, from near the ventral aspect of the ganglionic collar, a pair of nerves (7), each of which soon dilates into a large ganglion (8), from whence are derived the nerves of the internal labial tentacles (9) and also other gangliform nerves (10), distributed to what Professor Owen regards as the olfactory apparatus; lastly, the anterior collar gives off nerves (11) which penetrate the muscular integument and supply the infundibulum.

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* Descriptive and Illustrated Catalogue of the Physiological Series of Comparative Anatomy contained in the Museum of the Royal College of Surgeons of England, vol. iii. part 1. p. 187.

† Cyclopædia of Anatomy and Physiology, art. CEPHALOPODA.

(1570.) In the Dibranchiate Cephalopods, the nerves derived from that portion of the brain that may be regarded as analogous to the anterior collar of *Nautilus* supply the locomotive sucker-bearing arms, the labial apparatus, and also the auditory organs (fig. 294, *c*, *d*); but the latter have not been found to exist in *Nautilus Pompilius*.

(1571.) There is no possibility of doubting that the above nerves, distributed as they are to the complex sensitive tentacula connected with the head and parts of the mouth, represent the fifth pair in the Vertebrata—their general distribution and semi-ganglionic character being, *cæteris paribus*, precisely similar; so that those portions of the brain of vertebrate animals from whence the trifacial and auditory nerves originate may reasonably be compared with the anterior subœsophageal collar of the Cephalopoda.

(1572.) The posterior subœsophageal ganglionic ring (fig. 291, 4) may be compared to the medulla oblongata of quadrupeds. In *Nautilus* it gives origin, 1st, to numerous nerves (13) which, after a short course, plunge into the muscular parietes of the body, to which they are distributed; 2ndly, to two large cords (14) which terminate by becoming gangliform (16), and supply the branchial apparatus and the viscera—thus representing the par vagum in their distribution, and in like manner communicating with branches apparently corresponding with the sympathetic nerves that are spread out over the heart and ramifications of the vascular system; lastly, slender nerves, allied to the sympathetic, accompany the vena cava into the abdomen.

(1573.) Such being the arrangement of the principal nervous ganglia and the general distribution of the nerves, we must now turn our attention to the instruments of sensation possessed by these comparatively highly-gifted animals; and these, as we shall soon perceive, are in all respects correspondent, in the perfection of their structure, with the exalted condition of the brain, and, from their peculiar organization, highly interesting to the physiologist.

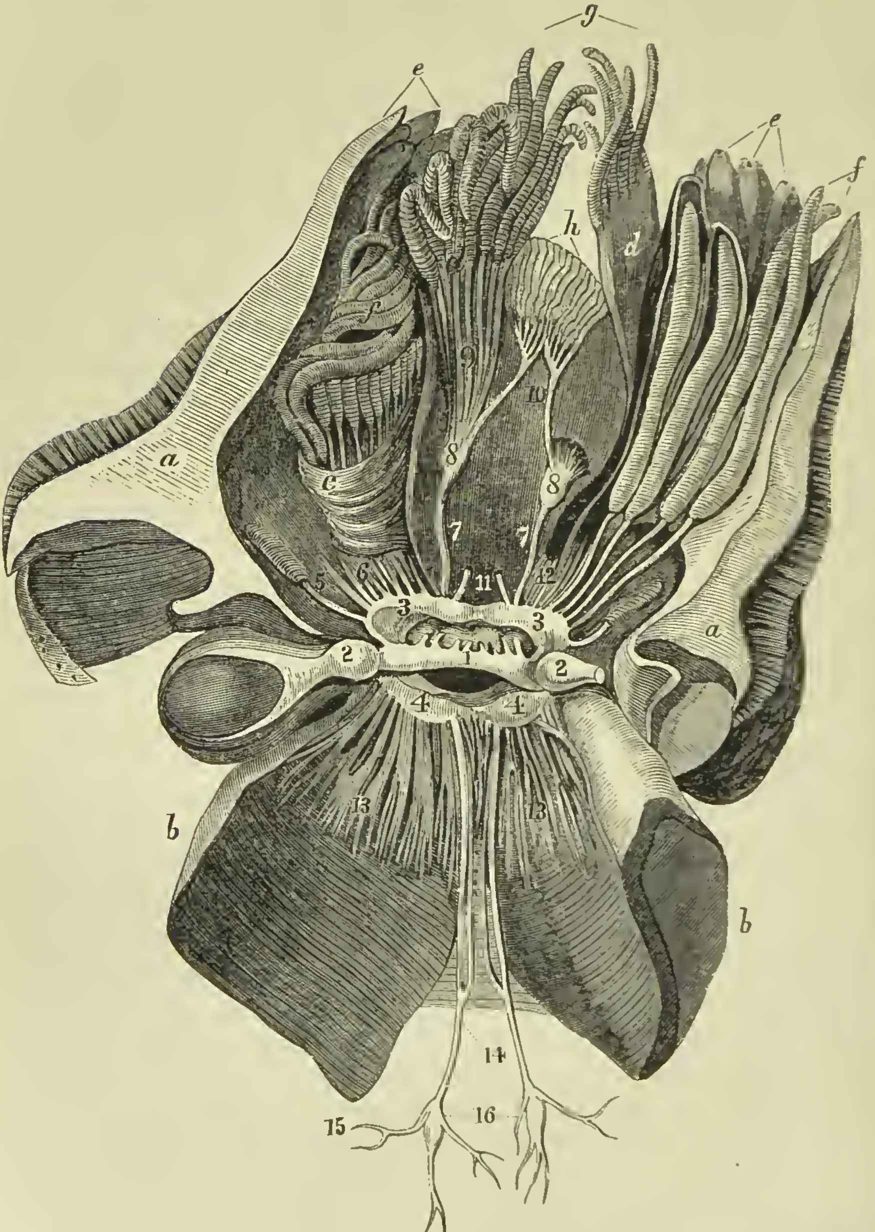
(1574.) The senso of touch, as might naturally be expected, resides principally in the tentacula, or feet, as they are generally termed, placed around the mouth, and forming, as we have already seen, instruments of locomotion as well as prehensile organs. In the Dibranchiate Cephalopods these tentacula are armed with the tenacious suckers described in a former page; but in the *Nautilus* they are so peculiar, both in structure and office, that a more elaborate description of them becomes requisite in this place, for which, of course, we are necessarily indebted to the same source from whence we have derived all our information relative to this extraordinary animal.

(1575.) The head of *Nautilus* (fig. 284) is of a conical form, and of a much denser texture than the analogous part in the Dibranchiate Cephalopods: it is excavated in such a manner as to form a receptacle or sheath, into which the mouth and its more immediate appendages can be wholly retracted, and so completely concealed as to require the aid of dissection before they can be submitted to examination. The orifice of this great oral sheath is anterior, its superior parietes being formed by a thick triangular hood (fig. 284, *n*) with a wrinkled and papillose exterior, while the sides give off numerous conical and trihedral processes (*o o o*): the inferior portion of the cone is thin, smooth, and concave, and rests upon the funnel (*i*). From the disposition of the hood, and the tough coriaceous texture of its substance, it is evident that this part is calculated to perform the office of an *operculum* by closing the aperture of the shell when the body of the animal is retracted.

(1576.) The lateral processes (*o o o*) are thirty-eight in number, nineteen on either side, irregularly disposed one upon another, and all converging towards the oral sheath; but as the hood itself consists apparently of two very broad digitations conjoined along the mesial line, twenty pairs of these lateral appendages may be enumerated. There is not the slightest appearance of acetabula, or suckers, upon any of these cephalic appendages; but their exterior surface is more or less rugose: each is traversed longitudinally by a canal, in which is lodged an annulated cirrus or tentacle (figs. 284, 291), which is about a line in diameter, and from 2 inches to 2½ inches in length. In the specimen examined, a few of the cirri were protruded from their sheaths to the extent of half an inch, but the rest were completely retracted, so as not to be visible externally; and on laying open some of the canals, the extremities of several were found as far as a quarter of an inch from the aperture; so that they appear to possess considerable projectile and retractile powers.

(1577.) To the above forty tentacula must be added four others of a different construction, which project immediately beneath the margin of the hood, like antennæ, one before and one behind each eye (fig. 284, *r*). These tentacles would seem at first sight to be constructed upon the same principles as the last; but on examining them attentively, they are found to be composed of a number of flattened circular disks appended to a lateral stem. Yet even all these organs of touch form but a small part of the tactile apparatus of the *Nautilus Pompilius*; for the mouth, lodged within the oral sheath, is surrounded with a series of tentacula even more numerous than those appended to the exterior of the head. Around the circular lip (fig. 289, *m*) which encloses the beak (*n*, *o*) are situated four *labial processes* (*g g*, *i i*): each of these processes is pierced by twelve canals, the orifices of which are disposed in a single but rather irregular series along their anterior margin; and every one of these canals contains a cirrus or tentacle rather smaller than those of the external digitations, although their structure is precisely similar (*h h*, *k k*). These cirri, like the former, receive large

Fig. 291.



Nervous system of *Nautilus Pompilius* (after Owen): *a a*, *b b*, cut edges of the mantle: *d*, *e*, *f*, *g*, retractile tentacula; *h*, presumed olfactory organ; 1, the supraœsophageal ganglion: 2 2, optic ganglia; 3 3, 4 4, subœsophageal ganglia; 5, 6, 7, 8, 9, nerves supplying the retractile tentacula; 10, nerves supplying olfactory organ; 11, 12, 13, nerves supplying the muscular integument; 14, 15, 16, nerves representing the sympathetic system.

nerves,—those supplying the external labial tentacles being derived immediately from the brain (fig. 291, 6 6), while those distributed to the internal labial tentacles proceed from a large ganglion (8) that is in communication with the œsophageal ring through the intervention of a considerable nervous trunk (7).

(1578.) In the Dibranchiate Cephalopods none of the above-described cirriferous processes are found to exist; but there is every evidence that the prehensile arms, and most probably the individual suckers appended to them, are highly sensitive to tactile impressions. Every one of the arms receives a large nerve, derived from the same portion of the œsophageal collar as that which gives origin to the tentacular nerves of *Nautilus*, which traverses its whole length, lodged in the same canal as the great artery of the limb. During this course the nerve becomes slightly dilated at short distances, and gives off from each enlargement numerous small nervous twigs which penetrate into the fleshy substance of the foot. Immediately after entering the arm and undergoing the dilatation above alluded to, every nerve furnishes two large branches, one from each side, which traverse the fleshy substance connecting the bases of the arms, to unite with the nerves of the two contiguous arms, so that all the nerves of the feet are connected near their origins by a nervous zone*,—an arrangement intended, no doubt, to associate the movements of the organs to which these nerves are appropriated.

(1579.) There is little doubt, from the character of the soft and papillose membrane which forms a considerable portion of the surface of the tongue, that both in the Nautilus and in the Dibranchiate Cephalopods the sense of taste is sufficiently acute—far superior, indeed, to what is enjoyed by any of the Gasteropod Mollusca, and possibly even excelling that conferred upon fishes and others of the lowest Vertebrata that obtain their food under circumstances such as render mastication impossible, and the perception of savours a superfluous boon.

(1580.) That the CEPHALOPODA are provided with a delicate sense of smell, and attracted by odorous substances, is a fact established by the concurrent testimony of many authors, although in the most highly organized genera nothing analogous to an olfactory apparatus has as yet been pointed out: nevertheless, in *Nautilus*, Professor Owen discovered a structure which he regards, with every show of probability, as being a distinct organ of passive smell, exhibiting the same type of structure that is met with in the nose of fishes, and, from the circumstance of its being the first appearance of an organ specially appropriated to the perception of odours, well deserving the attention of the physiologist. We may here premise that the exercise of this function in creatures continually immersed in water must depend upon conditions widely differing from those which confer the power of smelling upon air-breathing animals. In the latter, the odorant particles, wafted by the breeze to a distance and drawn in by the breath, are made to pass, by the act of inspiration, along the nasal passages, and, being thus examined with a minuteness of appreciation proportionate to the extent of the olfactory membrane, give intimations of the existence of distant bodies scarcely inferior to those obtained from sight and sound. But, in an aquatic medium, information derived from this sense must be restricted within far narrower limits, inasmuch as the dissemination of odoriferous particles must necessarily be extremely slow, and the power of perceiving their presence comparatively of little importance, seeing that the extent to which it can be exercised is so materially circumscribed. Smell, in aquatic animals, is therefore apparently reduced to a mere perception of the casual qualities of the surrounding element, without any power of inhaling odours from a distance. Simple contact between a sufficiently extensive sentient surface and the water in which it is immediately immersed is all that is requisite in the case before us; and if an organ can be pointed out, constructed in such a manner as to adapt it to fulfil the above intention, there can be little hesitation in assigning to it the office of an olfactory apparatus.

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* Cuvier, Mémoire sur la Poulpe, p. 36.

(1581.) In *Nautilus*, the part indicated by Professor Owen* as appropriated to the sense of smell consists of a series of soft membranous laminæ (fig. 289, *l*; fig. 291, *h*) compactly arranged in a longitudinal direction, and situated at the entry of the mouth, between the internal labial processes. These laminæ are twenty in number, and are from one to two lines in breadth, and from four to five in length; but they diminish in this respect towards the sides. They are supplied by nerves (fig. 291, 10) from the small ganglia (8) which are connected with the ventral extremities of the anterior subœsophageal ganglia, and from which the nerves of the internal labial tentacula are likewise given off.

(1582.) The structure of the eyes in the two divisions of the CEPHALOPODA differs remarkably, and in both is so entirely dissimilar from the usual organization met with in other classes of animals, that we must invite the special attention of the reader to this portion of their economy.

(1583.) In the TETRABRANCHIATA, of which the *Nautilus* is the only example hitherto satisfactorily investigated, according to Professor Owen's observations† the eye appears to be reduced to the simplest condition that an organ of vision can assume without departing altogether from the type which prevails throughout the higher classes: for although the light is admitted by a single orifice into a globular cavity, or *camera obscura*, and a nerve of ample size is appropriated to receive the impression, yet the parts which regulate the admission and modify the direction of the impinging rays were, in the specimen examined, entirely deficient. In this structure of the eye, observes Professor Owen‡, the *Nautilus* approximates the Gasteropods, numerous genera of which, and especially the PECTINIBRANCHIATA of Cuvier, present examples analogous in simplicity of structure, and in a pedicellate mode of support and attachment to the head. Moreover, as the Pearly Nautilus, like the latter group of mollusks, is also attached to a heavy shell, and participates with them in the deprivation of the ordinary locomotive instruments of the Cephalopods, the anatomist whose remarks we quote hence deduces the more immediate principle of their reciprocal inferiority with respect to their visual organ, observing that it would little avail an animal to discern distant objects when it could neither overtake them if necessary for food, nor avoid them if inimical to its existence.

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* Mem. on Nautilus, p. 41.

† *Loc. cit.* p. 39 *et seq.*

‡ *Op. cit.* p. 51.

(1584.) The eyes of *Nautilus* (fig. 284, *m*) are not contained in orbits, but are attached each by a pedicle to the side of the head, immediately below the posterior lobes of the hood. The ball of the eye is about eight lines in diameter; and although contracted and wrinkled in the specimen examined, it appeared to have been naturally of a globular form, rather flattened anteriorly. The pupil was a circular aperture, less than a line in diameter, situated in the centre of the anterior surface of the eye. This small size of the pupil in *Nautilus*, which contrasts so remarkably with the magnitude of that aperture in the Dibranchiate Cephalopods, Professor Owen suggests is most probably dependent on the great degree of mobility conferred upon the eye of the *Nautilus* in consequence of its attachment to a muscular pedicle, which enables it to be brought to bear with ease in a variety of directions; whilst in the higher Cephalopoda, corresponding motions of the head and body, on account of the more fixed condition of the eye in them, would have been perpetually required, had not the range of vision been extended to the utmost by enlarging the pupillary aperture.

(1585.) The principal tunic of the eye is a tough exterior membrane or sclerotic (fig. 291), thickest posteriorly, where it is continued from the pedicle, and becoming gradually thinner to the margins of the pupil. The optic nerves, after leaving the optic ganglions (2), traverse the centre of the ocular pedicles, and, entering the eye, spread out into a tough pulpy mass which extends as far forwards as the semidiameter of the globe. This nervous tissue, as well as the whole interior of the cavity, is covered with a black pigment which is apparently interposed between the impinging rays of light and the sentient membrane. The contents of the eye-ball, of whatever nature they had been, had escaped by the pupil. If the eye had ever contained a crystalline lens, that body must have been very small; as otherwise, from the well-known effect of ardent spirits in coagulating it, it would have been readily perceived. What adds, however, to the probability of this eye being destitute of a crystalline humour is the total absence of ciliary plicæ, or any structure analogous to them. In some parts of the cavity a membrane could be distinguished which had enveloped the fluid contents of the eye; but it had entirely disappeared at the pupil, which had in consequence freely admitted the preserving liquid into the interior of the globe.

(1586.) However much is still left to be ascertained by future observations, we learn from the above able exposition of the appearances detected on examining the solitary example of a visual organ of this description hitherto met with, that the eye of the *Nautilus* exhibits every indication of inferiority of construction when compared with that of the Dibranchiate tribes. Encased in no orbital cavity, and consequently unprovided with any other muscular apparatus than the fleshy pedicle whereby it is connected with the head—unprotected by eyelids and devoid of lacrymal appendages—without either transparent cornea, aqueous humour, iris, or crystalline lens—and, moreover, coated internally with a dark pigment, apparently situated *in front* of the nervous expansion which represents the retina, instead of behind it in the usual position of the choroid tunic—all these are facts calculated to arrest the attention of the physiologist, and excite the surprise of every observer who studies on a large scale this part of the animal economy.

(1587.) The eyes of the Dibranchiate Cephalopoda are not less remarkable in their construction than those of the *Nautilus*, and from their greater complexity will require a more elaborate description. In order to simplify the details connected with this portion of our subject as much as possible, we shall describe separately, as forming distinct parts of the ocular apparatus met with in the common Cuttle-fish (*Sepia officinalis*), first, the *orbit*; secondly, the *globe of the eye*; thirdly, *the chamber of the optic ganglion*; and fourthly, the *muscles* of the visual organ.

(1588.) The *orbit* differs from that of all other classes of animals, inasmuch as it is a cavity circumscribed on all sides and covering even the front of the eye*. The bottom of the orbital cavity is cartilaginous, being partially formed by a process derived from the cranial cartilage; but elsewhere it is made up of the common fleshy integument of the body (fig. 292, *d d*, *e*): becoming gradually attenuated, the skin (*b*) passes over the anterior portion of the eye, where, being transparent (*f*), it represents the cornea, although it has no connexion with the eye-ball itself. Beneath the cornea the integument again becomes opake, and forms a thickened fold (*a*), which might be considered as the rudiment of an under eyelid. The orbit therefore forms a complete capsule, enclosing the whole of the apparatus of vision.

(1589.) The *globe of the eye* fills up the anterior part of the orbital chamber, and is remarkable from having no cornea properly so called; so that, on raising the transparent skin (*f*) which forms the exterior wall of the orbit and supplies the place of the cornea, the prominent surface of the crystalline lens (*o*) is found quite naked beneath it, neither an aqueous humour, nor an iris properly so called, being present. The outer coat of the eye (*g g*, *i*) represents the sclerotic tunic in Man: it is tough, fibrous, and of a silvery lustre; perforated anteriorly by a large round aperture, representing that which contains the cornea in the human eye, and pierced posteriorly by numerous foramina, through which the multitudinous branches derived from the optic ganglion (*k*) enter.

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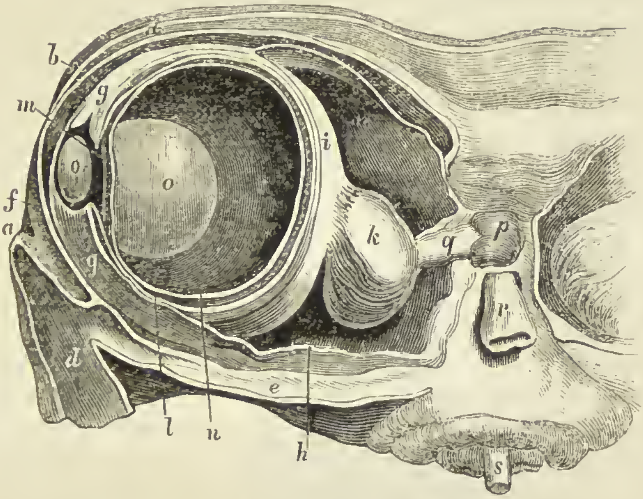
* Descriptive and Illustrated Catalogue of the Physiological Series of Comparative Anatomy contained in the Museum of the Royal College of Surgeons of England, vol. iii. part 1. pl. 52.

Fig. 292.



Anatomy of the eye of the Cuttle-fish. (After Cuvier.)

(1590.) The second tunic is usually regarded as the *retina*, occupying a singular situation and presenting a very anomalous structure. No choroid intervenes between this retina and the sclerotic, as is the case in the eye of Man; but numerous nervous branches given off from the optic ganglion (*k*), having penetrated into the interior of the eye through the cribriform sclerotic, immediately expand into a thick nervous membrane which lines the sclerotic tunic, and is continued forward to a deep groove in the substance of the crystalline lens, wherein it is implanted, so as to form a kind of ciliary zone (*m*), which is slightly plicated, and obviously assists in keeping the lens *in situ*.

(1591.) Between the retina and the vitreous humour is interposed a thick layer of black pigment, which, being thus strangely situated, has very naturally puzzled all physiological inquirers, inasmuch as it would apparently form an insurmountable barrier between tho rays of light and the retinal membrane. The researches of Professor Owen would seem, however, to have removed the difficulty presented by this hitherto incomprehensible and anomalous arrangement, as he has succeeded in discovering, in addition to the thick post-pigmental nervous expansion, a delicate lamella in front of the *pigmentum nigrum*, correspondent, in position at least, with the retina of vertebrate animals. "In the eyes of different *Sepiæ* which we had immersed in alcohol preparatory to dissection, we have, however, invariably found, between the pigment and the hyaloid coat, a distinct layer of opake white pulpy matter, of sufficient consistence to be detached in large flakes and easily preserved and demonstrated in preparations. We confess, however, that we can discover no connexion between this layer and the thick nervous expansion behind the pigment; but nevertheless we cannot but regard it as being composed of the fine pulpy matter of the optic nerve, and as constituting a true præ-pigmental retina*."

(1592.) It has been already stated that there are no chambers of aqueous humour; and we are but little surprised that, in animals destined to see objects contained in water, the existence of a refracting medium scarcely at all differing in density from the surrounding element should be dispensed with. To compensate, however, for this deficiency, the crystalline, as is the case in all the aquatic Vertebrata, is of short focus and great power, being, in fact, not merely, as it is generally described, a double convex lens, which is the usual shape of this important piece of the optic apparatus, but exhibiting that form of a simple magnifier most approved of by opticians as being best adapted to ensure a large field of view. Whoever is conversant with the principles upon which the well-known "Coddington lens" is constructed, will have little difficulty in appreciating the advantages derived by introducing a precisely similar instrument in the eye of the Cuttle-fish. The Coddington lens is a sphere of glass divided into two portions by a deeply-cut circular groove, which is filled up with opake matter. The lens of the Cuttle-fish is in like manner divided into two parts of unequal size (fig. 292, *o o*) by a circular indentation, wherein the post-pigmental retina, with its coat of dark varnish (*m*), is fixed, and thus a picture of the most perfect character is ensured. The crystalline penetrates deeply into the vitreous humour: the latter, enclosed in a delicate hyaloid membrane, fills up, as in Man, the posterior part of the eyeball; while the small space that intervenes between the posterior surface of the crystalline and the back of the ocular chamber sufficiently attests the shortness of the focus of so powerful a lens.

(1593.) The posterior portion of the orbital capsule is occupied by a large cavity quite distinct from the globe of the eye, although its walls are derivations from the sclerotic tunic, wherein is lodged the great ganglion of the optic nerve (*k*), imbedded in a mass of soft white substance. This supplementary chamber is formed by a separation of the sclerotic into two layers, of which one, already described (*i*), forms the posterior boundary of the eyeball, while the other (*h*), passing backwards, circumscribes the cavity in question. On entering the compartment thus formed, the optic nerve (*q*) dilates into a large reniform ganglion (*k*), almost equal in size to the brain itself; and from the periphery of the optic ganglion arise the numerous nervous filaments which, after perforating the posterior part of the globe of the eye, expand into the post-pigmental retina.

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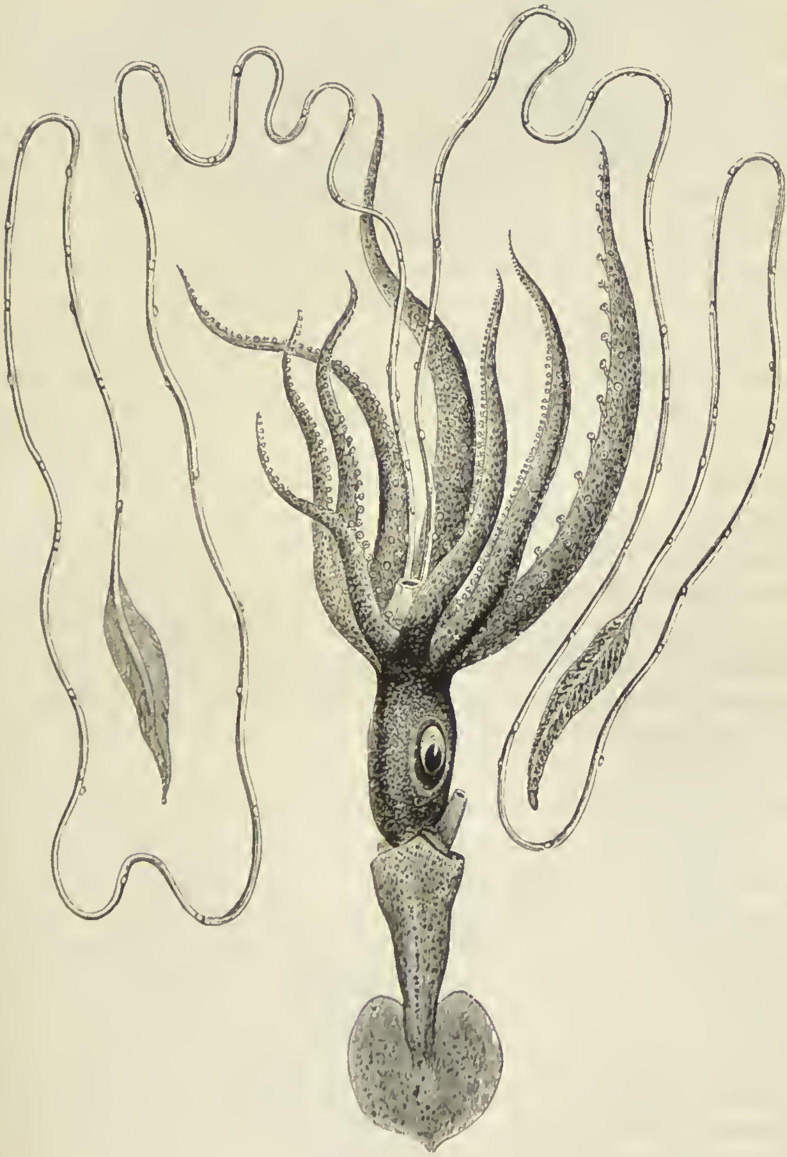
* Cyclopædia of Anatomy and Physiology, art. CEPHALOPODA.

(1594.) Between the globe of the eye (*g*) and the cornea (*f*) is a capacious serous cavity, which extends to a considerable distance towards the posterior part of the orbital chamber, and holds the same relation to the visual apparatus, and the cavity in which it is lodged, as the serous lining of the human pericardium does to the heart, and the fibrous capsule in which that viscus is lodged,—evidently forming an

Fig. 293.



Loligopsis Verani.

arrangement for facilitating the movements of the eye. The serous membrane which lines this cavity, after investing the inner surface of the cornea and the interior of the orbit, is reflected upon the outer surface of the sclerotic tunic of the eye, which it likewise covers, and moreover, at the front of the eyeball, enters the aperture which in the eye of a vertebrate animal would be occupied by the cornea, lines the chamber corresponding with that of the aqueous humour, and even passes over the anterior surface of the crystalline. This serous membrane Cuvier, very improperly, named the "*conjunctiva*"; but, as Professor Owen has suggested*, it is evidently rather analogous to the membrane of the aqueous humour, here excessively developed in consequence of the want of a cornea in the sclerotic aperture. This serous cavity is not, however, a completely-closed sac, but, as is frequently the case with the serous membranes of fishes and reptiles, is in communication with the surrounding medium, through the intervention of a minute orifice visible in the transparent tegumentary cornea.

(1595.) Four muscular slips are appropriated for the movements of this remarkable eye, and serve to direct the axis of the organ so as to ensure distinct vision; they arise principally from the orbital prolongations of the cranial cartilage, and are inserted into the sclerotic tunic.

(1596.) It is always interesting to the physiologist to observe the earliest appearance of a new system of organs, and witness the gradual development of additional parts, becoming more and more complicated as we advance from humbler to more elevated grades of the animal creation. The progressive steps by which the auditory apparatus of the Vertebrata attains to that elaborate organization met with in the structure of the human ear are not a little curious. In the simplest aquatic forms the central portion of the internal ear alone exists, imbedded in the as yet cartilaginous cranium. Gradually, as in fishes, semicircular canals, prolonged from the central part, increase the auditory surface, but still have no communication with the exterior of the body. In reptiles and birds, destined to perceive sonorous impressions in an aërial medium, a tympanic cavity and drum are superadded; and lastly, in the Mammiferous orders, external appendages for collecting and conveying sound to the parts within, complete the most complex and perfect form of the acoustic instrument.

(1597.) As far as is yet known, the Tetrabranchiate Cephalopods have no distinct organ of hearing; but in the Dibranchiata, an ear, lodged in an internal cranium, for the first time presents itself to our notice, and at the same time exhibits the lowest possible condition of a localized apparatus adapted to receive sounds.

(1598.) In the anterior and broadest part of the cartilaginous cranium†, where its walls are thickest and most dense, are excavated two nearly spherical cavities (fig. 294, *d*), which in themselves represent the osseous labyrinth of the ears. A vesicle or membranous sacculus (*c*), likewise nearly of a spherical form, is suspended in the centre of each of these cartilaginous cells by a great number of filaments, that are probably minute vessels. The two auditory nerves derived from the encephalon enter these cavities through special canals; and each, dividing into two or three branches, spreads out over the vesicle to which it is destined. The auditory vesicle itself is filled with a transparent glairy fluid, and contains, attached to its posterior part, a minute *otolith* (1, 2, 3), of variable shape in different genera, the oscillations of which doubtless increase the impulses whereupon the production of sound depends.

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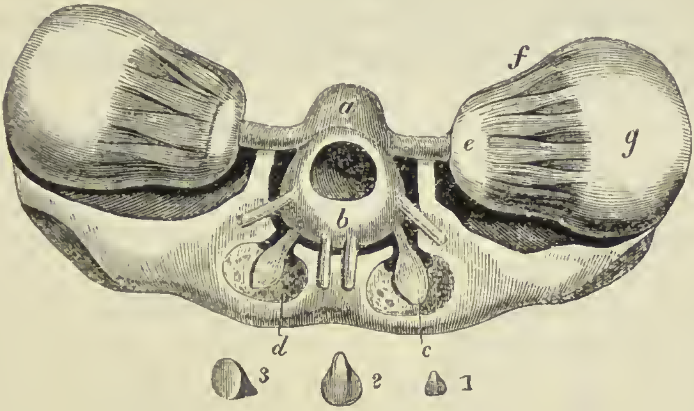
* Cyclopædia of Anatomy and Physiology, *loc. cit.* p. 552.

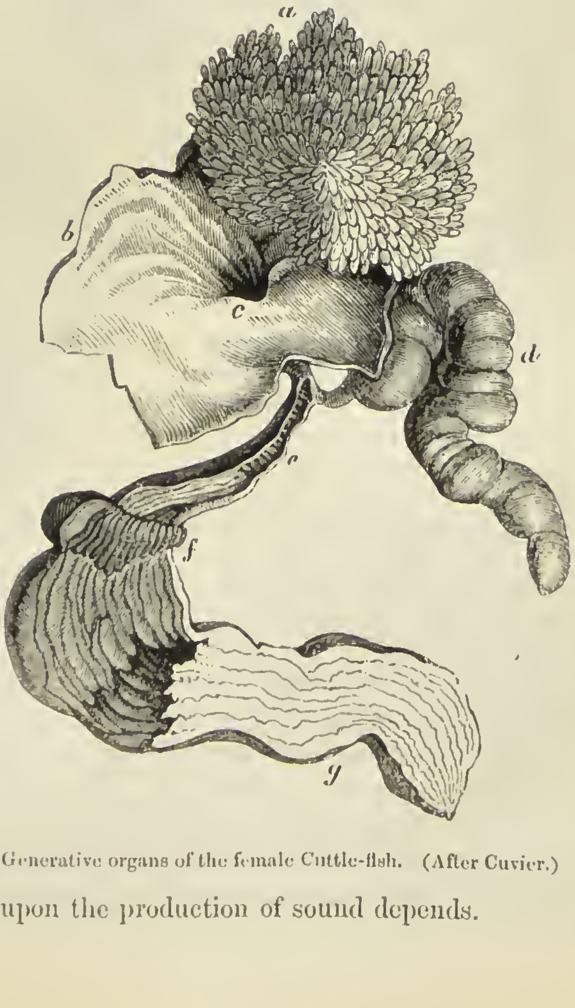
† Cuvier, Mémoire sur la Poulpe, p. 41.

Fig. 294.



Brain and auditory apparatus of the Cuttle-fish: *a*, *b*, brain; *c*, auditory apparatus; *d*, cavity in which it is lodged; *e*, *f*, *g*, the eye. 1, 2, 3, otolith.

Fig. 295.



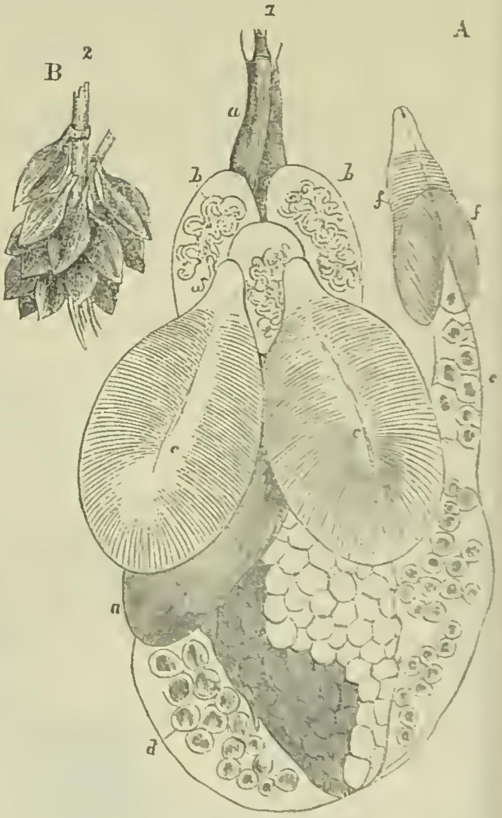
Generative organs of the female Cuttle-fish. (After Cuvier.)

(1599.) Such is the simplest form of an ear; and if the reader will compare the organ above described with that possessed by the highest Articulata, as, for example, the Lobster (§ 1047), the similarity of the arrangement will be at once manifest.

(1600.) All the Cephalopoda are diœcious; and the structure of the sexual organs both of the males and females is remarkable, inasmuch as it is peculiar to the class.

(1601.) In the females, the ovarian receptacle is lodged at the bottom of the visceral sac (fig. 290, *p*, *q*), enclosed in a distinct peritoneal pouch. The ovary itself is a large bag, the walls of which are tolerably thick; and, on opening it, it is found to contain a bunch of vesicular bodies, attached by short vascular pedicles to a circumscribed portion of its internal surface (fig. 295, *a*). These vesicles, the *ovisacs* or *calyces*, as they are called by comparative anatomists, are, in fact, the nidi wherein the ova are secreted; and if examined shortly before oviposition commences, every one of them is seen to contain an ovum in a more or less advanced stage of development. In this condition the walls of the ovisacs are thick and spongy; and their lining membrane, which constitutes the vascular surface that really secretes the egg, presents a beautiful reticulate appearance.

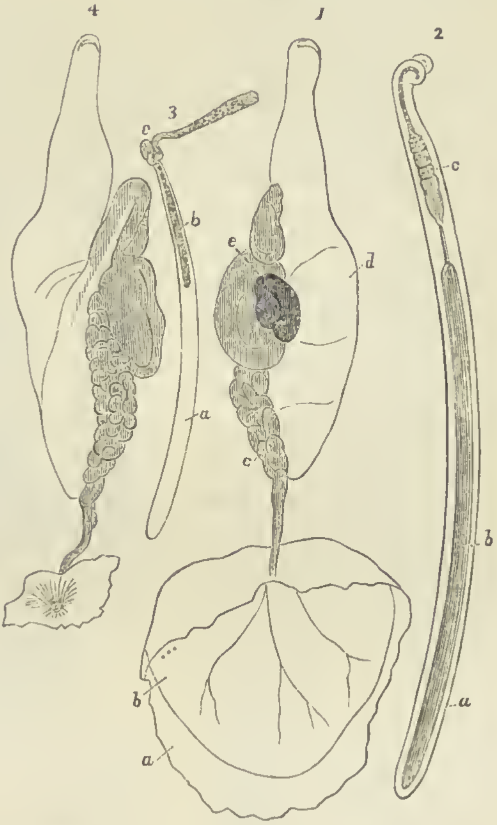
Fig. 296.



A. Generative organs of the female Cuttle-fish.
B. A bunch of eggs.

(1602.) If the contained ova be examined when nearly ripe for exclusion, each is found to be composed of a yelk or *vitellus* enclosed in a delicate vitelline membrane, and covered externally by a thicker investment, the *chorion*. When the ovum has attained complete maturity, the ovisac enclosing it becomes gradually thinned by absorption, and ultimately bursts, allowing the egg, now complete with the exception of its shell, to escape into the general cavity of the ovarium (*c*). The oviduct (*e*) communicates immediately with the interior of the ovarium by a wide orifice, the dimensions of which are proportioned to the size of the mature ova. It is generally single; but in some genera, as *Loligo* and the *Octopoda*, the canal derived from the ovary soon divides into two (*d*, *e*). The walls of the ovigerous duct are thin and membranous until near the external outlet, where they suddenly become thick and glandular, and, in many genera, surrounded with a very large laminated gland (*f*), through the centre of which the eggs have to pass before they issue from the body. It is the gland last mentioned that secretes the external horny covering of the egg—a defence which seems to be deposited in successive layers upon the outer surface of the previously existing chorion, and, when completed, forms a thick flexible case made up of concentric lamellæ of a dark-coloured corneous substance.

Fig. 297.



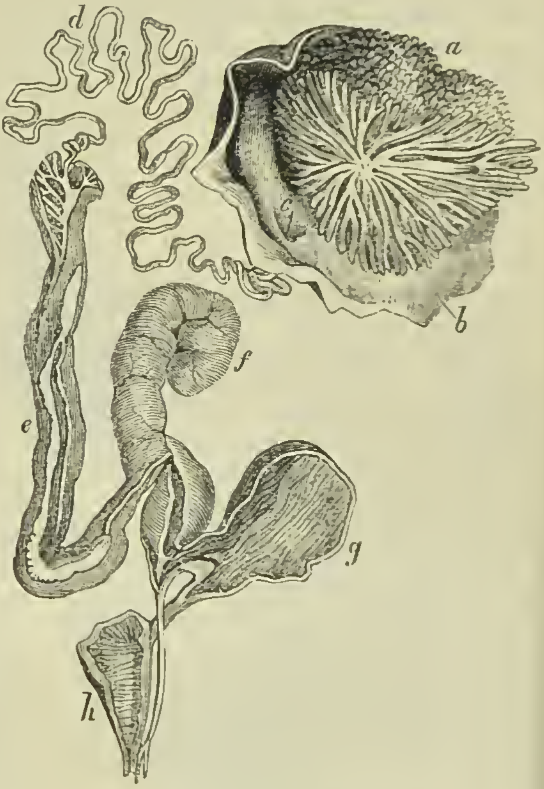
1. Male organs of the Cuttle-fish (*Sepia officinalis*), seen from before: *a*, tunic enveloping the testis; *b*, body of the testicle; *c*, convolutions of the vas deferens; *e*, commencement of the Needhamian canal; *d*, pouch of Needham. In fig. 4 the same parts are represented as seen from behind, the testicle being removed in order to show the commencement of the vas deferens. 2 and 3 represent the spermatophores of the same animal, much magnified: *a*, the external sheath; *b*, inner cylinder containing the spermatic fluid; *c*, the ejaculatory apparatus. In fig. 3 the spermatophore is shown in the act of discharging its contents.

(1603.) After extrusion, the ova of the different families of CEPHALOPODA are found agglutinated and fastened together into masses of very diverse appearance. The eggs of the common Cuttle-fish, frequently found upon the shore, are not inaptly compared by those ignorant of their real nature to a bunch of black grapes, to which, indeed, they bear no very distant resemblance, being generally aggregated in large clusters, and fastened by long pedicles either to each other or to some foreign body (fig. 296). The Argonaut carries its eggs, which are comparatively of small size, securely lodged in the recesses of its shell; while the ova of the Calamary, encased in numerous long gelatinous cylinders that conjointly contain many hundreds of eggs, are fixed to various submarine substances, and thus protected from casualties.

The form and arrangement of these bunches are no doubt dependent upon the peculiar character of the terminal gland found in the oviduct of the parent, whereby the last covering to the ova is furnished.

(1604.) Cuvier remarks that the male Poulpes must be less numerously met with than the female, as among the numerous specimens dissected by him scarcely one-fifth were of the former sex.

Fig. 298.



Generative organs of the male Cuttle-fish. (After Cuvier.)

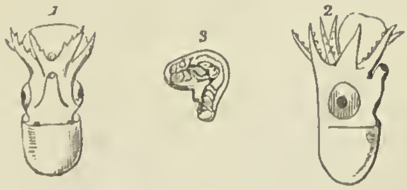
(1605.) The various parts of the male generative apparatus are remarkably similar, both in structure and arrangement, to the corresponding portions of the sexual organs of the female. The testicle strikingly resembles the ovary both in its outward form and internal arrangement: like that viscus, it consists of a capacious membranous sac (fig. 298, *b*); and on opening this there is found, attached to a small portion of its inner surface, a large bundle of branched cæca (*a*), in which no doubt the seminal fluid is elaborated. These strangely disposed seminigerous cæca have apparently no proper excretory ducts; but the impregnating fluid secreted by them is, as it would seem, poured into the general cavity of the sac, exactly in the same manner as the ova in the other sex, and, being allowed to escape from this reservoir through a wide orifice (*c*), it enters the *vas deferens*. The canal last mentioned (*d*) is long, slender, and very tortuous, but after many convolutions it enters a wider canal (*e*), called by Cuvier *vesicula seminalis*, the interior of which is divided by imperfect septa; and, its texture being apparently muscular, this part of the excretory apparatus may possibly, by its contractions, expel the spermatic fluid from the body. On issuing from the seminal vesicle, the semen passes the extremity of an oblong gland (*f*), which Cuvier denominates the *prostate*: its structure is compact and granular; and it seems to be destined to furnish some accessory fluid subservient to impregnation. Having passed the prostate, the ejaculatory duct communicates with a large muscular sacculus (g), the contents of which are very extraordinary. This sacculus is, in fact, filled with innumerable white filaments, each about half an inch in length, arranged parallel to each other, and disposed with much regularity. There are three or four rows of them, one above another, entirely filling the sac; and they are maintained *in situ* by a delicate spiral membrane, but are quite unconnected with the sac itself. The filaments when taken out, even long after the death of the Cephalopod, exhibit, when moistened, various contortions, and by some have been regarded as *Entozoa*.

(1606.) These remarkable spermatic filaments (the famous "filament machines" of Needham) present, in fact, a very complicated structure. Their form varies in different species; but in their essential composition they are all found to consist of a long tubular sheath (fig. 297, 2, 3), composed of two membranes, and enclosing a long tube, convoluted upon itself like an intestine, which is filled with an opake white fluid, in which are contained millions of zoosperms; and the apparatus to which it is attached anteriorly constitutes an ejaculatory instrument, by the aid of which the spermatic secretion is forcibly ejected. These "*spermatophores*," as they have been named by Milne-Edwards, serve as vehicles for the conveyance of the seminal fluid into the generative system of the other sex, notwithstanding the absence of any copulatory apparatus.

(1607.) A most extraordinary modification of the male sexual organs is met with in the males of the *Argonaut*, *Tremoctopus*, and probably of other kindred genera, in which one of the arms is so strangely modified, both in its shape and structure, that Cuvier mistook it for a parasite, describing it, under the name of *Hectocotyles*, as "a long, parenchymatous worm, compressed at the anterior extremity, where the mouth is situated, having its inferior surface furnished with suckers, from sixty to a hundred in number, arranged in pairs, and furnished with a sacculus, situated at the posterior extremity of its body, which is filled with the folds of the oviduct."

(1608.) The *Hectocotylus Argonautæ**, as this strange appendage is still called, is, in fact, a portion of the Argonaut itself, developed in a remarkable sac, which supplies the place of the left arm of the third pair. The male Argonaut

Fig. 299.



1, 2. Male Argonaut, of the natural size, represented in front and in profile, showing the sacculus in which the Hectocotylus is contained; from a specimen preserved in spirit. 3. Sacculus, in which the Hectocotylus may be distinguished through its transparent walls. The specimen from which this figure was taken having been preserved in spirit, is, of course, contracted in all its dimensions.

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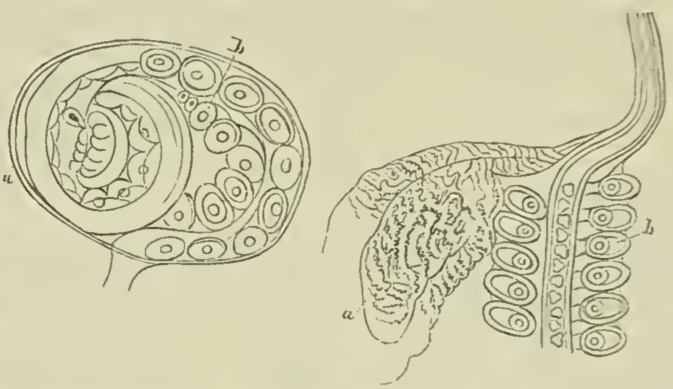
* Henri Müller, Ann. des Sc. Nat. 1851.

(fig. 299, 1, 2) is of very small size as compared with the female, being not more than an inch in length, and has no shell; moreover the upper pair of arms are not, as in the female (fig. 283), expanded into velæ, but are pointed. The sac above alluded to, on being opened, is invariably found to contain a solitary Hectocotylus, the dilated portion of which is attached at its base, whilst the rest of this remarkable organ is free and rolled up towards that side upon which the suckers are situated; but as soon as the sac is opened, or when it is ruptured by the movements of the contained Hectocotylus, the latter unfolds itself (fig. 301, *a*), assuming so exactly the appearance of a parasitic animal that the mistake committed by Cuvier is by no means surprising. The Argonaut itself possesses a well-developed testis, according in its structure with that of ordinary Cuttle-fishes, and which contains spermatozoids in different stages of development; but its excretory duct terminates in the Hectocotylus, which is evidently nothing more than one of the arms of the Argonaut thus strangely developed. But, what is stranger still, this arm, arrived at maturity, detaches itself from the Argonaut, and from that moment enjoys an independent existence. It lives adherent to a female Argonaut, which it impregnates by a real coitus; so that in this respect, as well as by its movements, and by the length of its life after its detachment, it might be mistaken for a complete male animal. Still it cannot be regarded as an independent being, seeing that it has no alimentary apparatus; neither is it the organ whereby the seminal fluid is produced, but simply a vehicle whereby the male secretion is transported. Well indeed does it deserve the epithet bestowed upon it by Cuvier, who, ignorant of its real nature, pronounced it "*un ver bien extraordinaire!*"

Fig. 300.

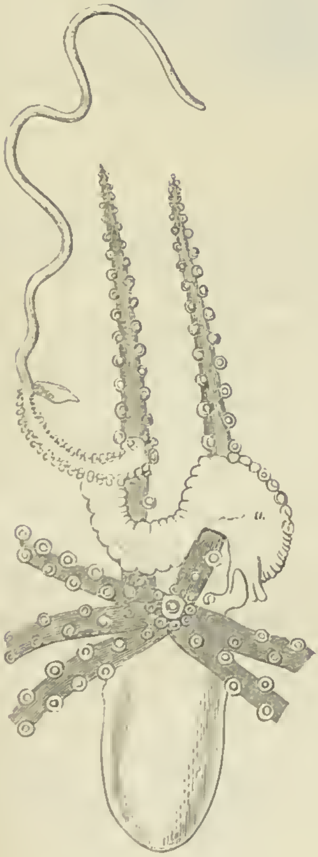


1. Sacculus of Argonaut laid open, showing the abnormal arm (*Hectocotylus*) folded up in its interior; magnified two diameters. 2. A portion of the Hectocotyliform arm, still further magnified: *a*, the sacculus laid open; *b*, the arm, showing the commencement of the "lash," and also the suckers, nervous ganglia, &c.

(1609.) From the pouch of Needham a short canal leads to the penis (*h*), a short, hollow, muscular tube, through which the fecundating fluid is expelled.

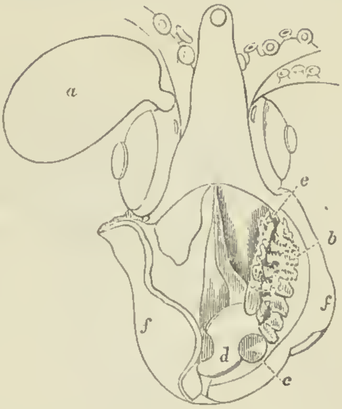
(1610.) Although we mean to defer any minute account of the development of the embryo *in ovo* until an examination of the eggs of oviparous Vertebrata shall afford more ample materials for elucidating this important subject, it will be as well in this place briefly to notice the condition of the young Cephalopods previous to their escape from the egg, wherein the first part of their growth is accomplished. Before the egg is hatched, the fœtal Cuttle-fish already presents all the organs essential to its support and preservation: the tentacula upon the head, the eyes, the respiratory apparatus, and even the ink-bag, which in the earlier stages of growth were quite undistinguishable in the germ of the future being (fig. 303, 1), slowly make their appearance; so that before birth the little creature presents most of the peculiarities which characterize the species to which it belongs. But the most prominent feature that strikes the attention of the physiologist is the remarkable position of the duct communicating between the yelk of the egg (the great reservoir of nourishment provided by nature for the support of the fœtus whilst retained in the egg) and the alimentary canal of the as yet

Fig. 301.



Tremoctopus carina (male), showing the Hectocotylus (*a*) in its ordinary position.

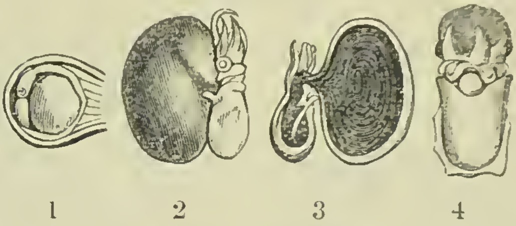
Fig. 302.



A male Tremoctopus, seen from the ventral aspect. The visceral sac has been laid open and the left half of the mantle turned aside, to show the branchia and the opening of the generative apparatus during the expulsion of the spermatophore. *a*, sacculus containing the Hectocotylus; *b*, branchia of the left side, with its branchial heart, *c*; *d*, the "bottle," from which the spermatophore (*e*) is in progress of expulsion; *f f*, the mantle.

imperfect *Sepia*. This communication, which in vertebrate animals is invariably effected through an opening in the walls of the abdomen, whereby the vitelline duct penetrates to the alimentary canal, here occupies a very unusual situation, being inserted into the head, through which it penetrates, by an aperture situated in the front of the mouth, to the œsophagus, where it terminates (fig. 303, 3).

Fig. 303.



Embryo of Cuttle-fish.

(1611.) Among the many interesting phenomena presented by the Cephalopoda, few are more remarkable than the extraordinary power which these animals possess of continually changing their colour in conformity with the varying tints of surrounding objects, affording a means of defence almost as efficient for concealment as the ejaculation of their inky fluid. It is indeed an extremely beautiful sight to witness the flickering hues of one of these animals, that seem to succeed each other with astonishing rapidity. In order to explain the cause of this very curious faculty, it is only necessary to examine with the microscope a portion of integument removed from the living animal, when it becomes at once apparent that the coloured layer of the skin is studded with innumerable pigment-cells (*chromatophores*), filled with colours that exactly correspond with the hues of the creature's body, and which individually possess a remarkable power of changing their shape and size, and thus modifying, by their contraction and expansion, the coloration of the integument*.

(1612.) Interesting as the subject is, our space will permit us to advert but very briefly to the important light which our comparatively recently acquired knowledge of the anatomy of the Cephalopod Mollusca has thrown upon the history of innumerable races of similarly constructed beings long extinct, the remains of which are extensively distributed through a variety of geological strata. The fossil Ammonites for example, the nature of which was previously inexplicable, were at once rendered intelligible by the discovery and description of the *Nau-*

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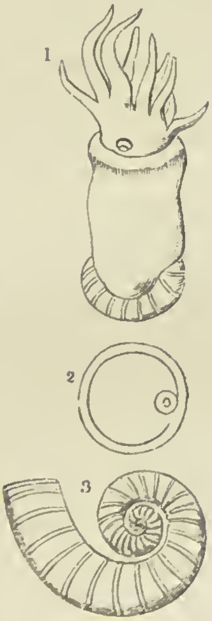
* This wonderful faculty of changing their colours, dependent on a similar organization of the *rete mucosum*, is possessed by fishes, frogs, and many other animals, as may be demonstrated by simply placing a few small trouts, gudgeons, or minnows in differently coloured earthen pans filled with clear water; and the phenomenon is rendered still more conspicuous by suddenly transferring them from the lighter to the darker coloured vessels, and *vice versâ*.

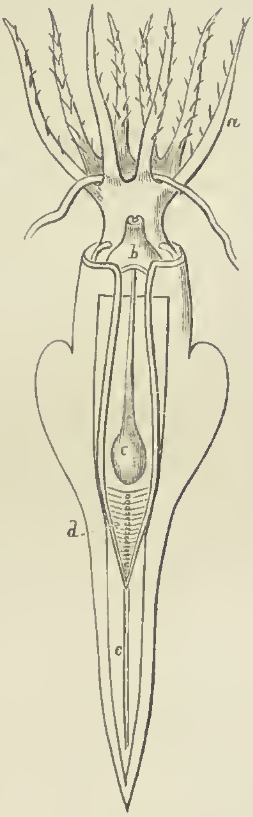
tilus Pompilius, to which in their structure they were evidently nearly related. The countless petrified remains known by the names of Hamites, Lituites, Orthoceratites, Cirthoceratites, and other allied forms are still representatives of the existing *Spirula* (fig. 304), which, although its structure even at the present day is but imperfectly understood, is manifestly a Cuttle-fish provided with a camerated shell constructed much after the same plan as that of the Nautilus; and even the *Belemnites,* so long a puzzle and a mystery to geologists, when restored by the labours of Professor Owen, as represented in fig. 305, unmistakeably confesses its relationship to the Cuttle-fishes we have been describing.

Fig. 304.



1 Animal of Spirula, exhibiting the shell *in situ.* 2. Transverse section, and, 3, lateral view of the shell removed from the body.

Fig. 305.



Belemnite restored: *a*, cephalic tentacles; *b*, siphon; *c*, ink-bag; *d*, *e*, section of shell. The outline exhibits the fin-like expansions of the integument.

(1613.) Leaving the Cephalopod Mollusca, we must bid adieu to the fourth grand division of the animal kingdom, and proceed in the next chapter to introduce the reader to beings organized according to a different type, embracing the most highly gifted and intelligent occupants of the planet to which we belong.

CHAPTER XXV.

VERTEBRATA.

(1614.) The fifth division of the animal kingdom is composed of four great classes of animals, closely allied to each other in the grand features of their organization, and possessing in common a general type of structure clearly recognizable in every member of the extensive series, although, of course, modified in accordance with the endless diversity of circumstances under which particular races are destined to exist. The immeasurable realms of the ocean, the rivers, lakes, and streams, the fens and marshy places of the earth, the frozen precincts of the poles, and the torrid regions of the equator, have all appropriate occupants, more favoured as regards their capacities for enjoyment, and more largely endowed with strength and intelligence, than any which have hitherto occupied our attention, and gradually rising higher and higher in their attributes, until they conduct us at last to Man himself. Fishes, restricted by their organization to an aquatic life, are connected by amphibious beings, that present almost imperceptible gradations of development, with terrestrial and air-breathing Reptiles: these, progressively attaining greater perfection of structure and increased powers, slowly conduct us to the active, hot-blooded Birds, fitted by their strength, and by the vigour of their movements, to an aërial existence. From the feathered tribes of Vertebrata, the transition to the still more intelligent and highly-endowed Mammalia is effected with equal facility; so that the anatomist finds, to his astonishment, that throughout this division of animated nature, composed of creatures widely differing among themselves in form and habits, an unbroken series of beings is distinctly traceable.

(1615.) The first grand character that distinguishes the vertebrate classes is the possession of an internal jointed skeleton, which is not. as in the preceding classes, extravascular and incapable of increase except by the successive deposition of calcareous laminæ applied to its external surface, but endowed with vitality, nourished by blood-vessels and supplied with nerves, capable of growth, and undergoing a perpetual renovation by the removal and replacement of the substances that enter into its composition.

(1616.) In the lowest tribes of aquatic Vertebrata the texture of the internal framework of the body is permanently cartilaginous, and it continues through life in a flexible and consequently feeble condition: but as greater strength becomes needful, in order to sustain more active and forcible movements, calcareous particles are found to be deposited in the interstices of the cartilaginous substance, and, in proportion as these accumulate, additional firmness is bestowed upon the skeleton, until at length it assumes hardness and solidity proportioned to the quantity of the contained earthy matter, and becomes converted into perfect bone.

(1617.) Phenomena precisely similar are observable in tracing the formation and development of the osseous system, even in those genera possessed, when arrived at maturity, of the most completely organized skeletons.

(1618.) In the very young animal the bones consist exclusively of cartilage; but as growth proceeds, earth becomes deposited by the blood-vessels in the as yet soft and flexible pieces of the skeleton, until by degrees they acquire density and strength as the animal advances towards its adult condition.

(1619.) The complete skeleton of a vertebrate animal may be considered as being composed of several sets of bones employed for very different purposes,—consisting of a central portion, the basis and support of the rest, and of various appendages derived from or connected with the central part. The centre of the whole osseous fabric is generally made up of a series of distinct pieces arranged along the axis of the body; and this part of the skeleton is invariably present; but the superadded appendages, being employed in different animals for various and distinct purposes, present the greatest possible diversity of form, and are many of them wanting in any given genus; so that a really complete skeleton, that is, a skeleton made up of all the pieces or elements which might, philosophically speaking, enter into its composition, does not exist in nature, inasmuch as it is owing to the deficiency of some portions and the development of others in particular races that we must ascribe all the endless diversity of form and mechanism so conspicuously met with in this division of the animal world.

(1620.) Nevertheless, although there is no such a thing in creation as a fully-developed skeleton, it will be necessary, in order to prepare the student for the contemplation of the numerous modifications met with in this portion of the animal economy, hereafter to be described, briefly to enumerate the component parts which might theoretically be supposed to enter into the construction of the framework of an animal; and thus by comparison he will be enabled, as we proceed, to appreciate more readily the variations from a general type apparent throughout the vertebrate classes. It may likewise be as well thus early to caution the anatomist who has confined his studies to the contemplation of the human body, against taking the skeleton of Man as a standard whereby to direct his judgment; for *Man*, so highly raised by his intelligence and mental powers above all other beings, is, so to speak, a monstrosity in the creation; and, so far from finding in the human frame the means of elucidating the laws of animal organization, it is found to have been constructed upon principles the most aberrant and remote from those which an extensive investigation of the lower animals has revealed to the physiologist.

(1621.) A skeleton, described generally, is made up of the following portions: first, of a chain of bones, placed in a longitudinal series along the mesial line of the back, and more or less firmly articulated with each other, so as to permit certain degrees of flexure. These bones, examined individually, present various additional parts destined to very different ends: some defend the central axis of the nervous system from external violence; others, when present, guard and enclose the main blood-vessels; and the rest, acting as prominent levers, either serve to give insertion to the muscles which move the spine, or afford additional security to the articulations between the vertebral pieces. Those vertebræ which defend the posterior portions of the nervous axis, usually called the *spinal cord*, constitute the *spine*; while those enclosing the anterior extremity of the nervous axis, which, for reasons hereafter to be explained, becomes dilated into large masses forming collectively *the brain*, are by the human anatomist distinguished as the *cranium* or *skull*.

(1622.) Secondly, we find appended to the cranial or cephalic portion of the spine, a set of bones disposed symmetrically, and forming the framework of the face: these bones, it is true, have by many Continental writers been regarded as constituting additional vertebræ, the parts of which are still recognizable, although amazingly modified in shape, so as to enclose the different cavities wherein the senses of vision and smell, as well as the organs of mastication, are situated. We shall not, however, waste the time of the student by considering in this place the as yet unsettled and vague opinions of transcendental anatomists upon this subject; it is sufficient for our purpose merely to indicate the facial bones as appendages to the cranial vertebræ, avoiding for the present further discussion concerning them.

(1623.) Another most important addition to the central axis of the skeleton is obtained by the provision of lateral prolongations, derived from the transverse processes of the vertebræ, which form a series of arches largely developed at certain points, so as more or less completely to embrace the principal viscera, and give extensive attachment to muscles serving for the movements of the body.

(1624.) The first set of arches is appended to the lateral portions of the cranial vertebræ, and the bones thus derived enter largely into the composition of the respiratory apparatus. In Man this important portion of the skeleton is reduced to a mere rudiment, distinguished by the name of the *os hyoides*; and in the human subject its relations and connexions with the surrounding parts are so obscurely visible, that the student is scarcely prepared to witness the magnitude and importance of the hyoid framework in other classes, or the amazing metamorphoses which, as we shall afterwards see, it undergoes.

(1625.) Behind the hyoid apparatus, other arches are attached to the transverse processes of the spinal vertebræ, called *ribs*; and the study of these appendages to the spine is one of the most interesting points in the whole range of osteology. In Fishes, wherein respiration is effected entirely by the movements of largely-developed hyoid bones, the ribs are mere immoveable derivations from the transverse processes of the vertebræ, and serve exclusively for the attachment of muscles. In Reptiles, respiration is still accomplished by the os hyoides; and the ribs, thus performing a secondary office, become convertible to different uses, and assume various forms and proportions. In the Amphibious Reptiles, the most nearly approximated to Fishes, they either do not exist at all, as being needed neither for respiration nor locomotion, or they are represented by minute and almost imperceptible rudiments appended to the extremities of the transverse processes of the vertebræ. In Serpents, the ribs are wanted for locomotion, and are accordingly developed from the head nearly to the tail, forming a series of strong arches, articulated at one extremity with the vertebral column by a very complete joint, but at the opposite extremity they are loose and unconnected. In proportion, however, as the hyoid bones, with the larynx, of which they form an important part, become converted into a vocal apparatus (as they gradually do), the ribs, assuming more complete development in a certain region of the spine, and being augmented by the addition of a sternal apparatus, form a complete thoracic cavity, and thus become the basis of those movements of the body which in hot-blooded animals are subservient to respiration.

(1626.) The next additions required to complete the skeleton are two pairs of locomotive limbs, representing the legs and arms of Man. Infinitely diversified as are these members both in form and office, they are, when philosophically considered, found to be constructed after the same type. Both the anterior and posterior limbs, when fully organized, consist of similar parts, most of which are met with in the limbs of the human skeleton. Three bones constitute the shoulder, called respectively the *scapula*, the *clavicle*, and the *coracoid bone*. Three bones in like manner sustain the hinder extremity—the *ilium*, the *ischium*, and the *pubis*; and these evidently represent individually the corresponding pieces found in the shoulder, but differently named. The formation of the limbs is likewise strictly parallel: a single bone articulates with the osseous framework of the shoulder, or of the hip, called in one case the *humerus*, in the other the *femur*; two bones form the arm—the *radius* and *ulna*; and two likewise enter into the composition of the leg—the *tibia* and *fibula*. The hand and foot are each supported by a double series of small bones, forming the *carpus* of the one, and the *tarsus* of the other; and in like manner consist of similar pieces, five in number, called the *metacarpal* or *metatarsal* bones, and of the *phalanges*, or joints of the fingers and toes.

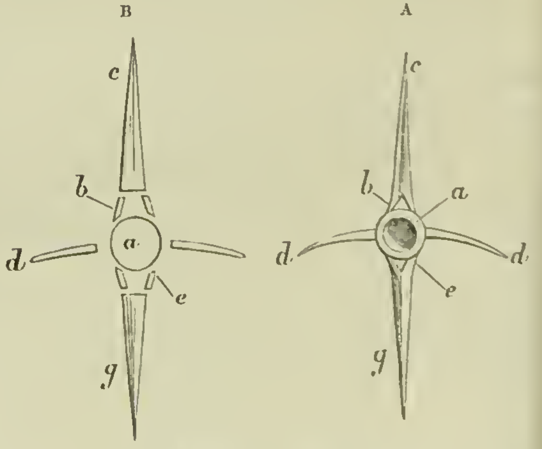
(1627.) A perfect or typical skeleton must therefore be supposed to consist of all the before-named portions: namely, 1, the cranial and spinal vertebræ; 2, the face; 3, an elaborately-formed hyoid framework; 4, the ribs; 5, a sternal system of bones, constituting, in conjunction with some of the ribs, a *thorax*; and 6, of four locomotive extremities, made up of the parts above enumerated as entering into their composition. Seldom, indeed, is it that the student will find even the majority of these portions of the osseous apparatus coexistent in the same skeleton; but, whatever forms of animals may hereafter present themselves for investigation, let the above description be taken as a general standard of comparison, and let all variations from it be considered as modifications of one grand and general type.

(1628.) We must, however, proceed one step further in this our preparatory analysis of the skeleton, and, instead of regarding the individual pieces of the osseous framework of an adult animal as so many simple bones, be prepared to find them resolvable into several distinct parts or *elements*, all or only a part of which may be developed in any given portion of the osseous system.

(1629.) In order to simplify as much as possible this important subject, we will select, first, what is generally considered as a single bone—one of the most complex *vertebræ* of a Fish for instance—and examine its real composition.

(1630.) This bone (fig. 306, A) is found to consist of a central portion (*a*), and of sundry processes derived therefrom, some of which the younger student of human anatomy would at once be able to call by their appropriate names. To the body of the bone (*a*) he finds appended the arch (*b*) which encloses the spinal cord, surmounted by its spinous process (*c*), and with equal facility he recognizes in the lateral processes (*d d*) the analogues of the transverse processes of the human spine; but here his knowledge fails him, inasmuch as he finds another arch (*e*) formed beneath the body of the bone, and moreover an inferior spinous process (*g*), neither of which have any representatives in the human body.

Fig. 306.



Elements of a vertebra.

(1631.) It is evident, therefore, that the human vertebræ are imperfectly-developed bones, and do not possess all the parts or elements met with in the corresponding portion of the skeleton of a Fish.

(1632.) The question, therefore, to be solved is this—how many elements exist in the most perfect vertebra known? and this being once satisfactorily settled, it is easy to detect the deficiencies of such as are less completely developed.

(1633.) Taking the example above given as a specimen of a fully-formed vertebra, it has been found to be divisible into the following pieces, all or only a part of which may be present in other vertebræ even belonging to the same skeleton; and these parts are represented detached from each other in the diagram which accompanies the figure (fig. 306, B). They are, 1st, the centre or body of the bone; 2ndly, two elements (*b b*), which embrace the spinal marrow; 3rdly, the superior process (*c*); 4thly, the two transverse processes (*d*); 5thly, two elements forming the inferior arch, and enclosing the principal blood-vessels (*e*); and 6thly, an inferior spinous process (*g*).

(1634.) With this key before us, we are able with the utmost ease to comprehend the structure of any form of vertebra that may offer itself. Thus, in different regions of the back of the same Fish, the composition of the vertebræ is totally different: near the tail the vertebræ consist of the body (*a*), the superior arch (*b*) and spinous process (*c*), and the inferior arch (*e*) and spinous process (*g*). In the neighbourhood of the head, however, neither the inferior arch nor spinous process are at all developed; but the transverse processes, which were deficient in the former case, are here of great size and strength. It is obvious, therefore, that the form of a vertebra may be modified to any extent by the simple arrest of the development of certain elements and the disproportionate expansion of others, until at length it becomes scarcely recognizable as constituting the same piece of the skeleton.

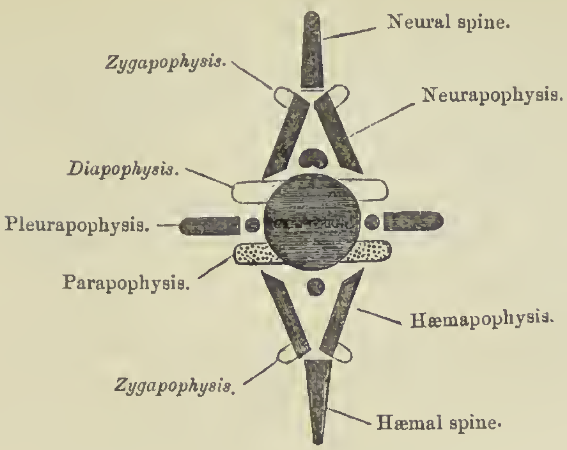
(1635.) Who would be prepared to expect, for example, that the occipital bone of the human head was merely a modification of a few of the elements of the Fish's vertebra above described enormously expanded, in order to become adapted to altered circumstances? And yet, how simple is the transition! By removing the inferior arch (*e*) and spinous process (*g*), and slightly reducing the proportionate length of the transverse processes (*d*), we arrive at the form of a human vertebra, which exhibits precisely similar elements. Enlarge the arches (*b b*) that surround the spinal axis of the nervous system, increase the size of the superior spinous element (*c*), and we have the occipital bone of a Fish; and from hence, through a few intermediate links, we arrive almost imperceptibly at the occipital bone of the human cranium,—the main differences being that the body is in Man divided into two lateral halves, while the superior arches (*b*) become spread out so as adequately to defend the prodigiously-developed masses of the brain, to which in the human body they correspond.

(1636.) One other illustration of this interesting subject. What bones compose a completely-formed thorax? In Man we find, as every tyro knows, 1st, the *dorsal vertebræ*; 2ndly, the *ribs*, with their cartilages; and 3rdly, the *sternum*. But it is not in Man that we must expect a perfectly-developed thoracic framework; it is in the Birds, which are destined to rise in the air by the assistance of their proportionately-powerful thoracic extremities. If, therefore, we examine the thorax of a Bird, we find it composed of pieces which in Man are absolutely wanting: we see, 1st, the *vertebræ*; 2ndly, the *dorsal ribs*, firmly articulated on each side both with their bodies and transverse processes; 3rdly, the *sternal ribs*, extending from the ribs last mentioned to the sternum; and lastly, the *sternum*, composed, as we shall afterwards see, of various elements not found in the human body. If we prosecute our survey a little further, we shall find this portion of the skeleton offering the greatest possible variety as regards the presence or absence of the elements above enumerated: thus, in the *Frog* we have vertebræ and sternum, but no ribs; in the *Serpent*, vertebræ and dorsal ribs, but no sternum or sternal ribs; in Man the sternal ribs are represented by the costal cartilages; and thus a thorax of every required description is constructed by adding or taking away, expanding or contracting certain elements, all of which a typical skeleton might be supposed to contain developed in a medium condition.

(1637.) Comparison of the skeleton of a Fish with those of the higher animals demonstrates that the natural arrangement of the parts of the endoskeleton is in a series of segments succeeding each other in the axis of the body. These segments are not, indeed, composed of the same number of bones in any class, or throughout any individual animal; but certain parts of each segment do maintain such constancy in their existence, relation, position, and offices, as to enforce the conviction that they are homologous parts, both in the constituent series of the same individual skeleton, and throughout the series of vertebrate animals. Each of these primary segments of the skeleton is designated a "vertebra," but with as little reference to the primary signification of the word as when the comparative anatomist speaks of a sacral vertebra. A vertebra is defined by Professor Owen as "*one of those segments of the endoskeleton which constitute the axis of the body and the protecting canals of the nervous and vascular trunks*;" such a segment may also support *diverging appendages*.

(1638.) A vertebra consists, in its typical completeness, of the elements or parts represented in the following diagram:—

Fig. 307.



(1639.) The names in the above diagram printed in Roman type signify those parts which, being usually developed from distinct and independent centres, have been named *autogenous* elements. The italics denote the parts more properly called processes, which shoot out as continuations from some of the preceding elements, and are termed *exogenous.*

(1640.) The autogenous elements generally circumscribe holes about the centrum, which in the chain of vertebræ form canals. The most constant and extensive canal is that formed above the centrum (fig. 307) for the lodgment of the main trunk of the nervous system (neural axis) by the elements thence termed *neurapophyses.* The second canal, below the centrum (fig. 307), is in its entire extent more irregular and interrupted; it lodges the central organ and large trunks of the vascular system (hæmal axis), and is usually formed by the *laminæ* which are therefore called *hæmapophyses.* At the sides of the centrum, most commonly in the cervical region, a canal is circumscribed by the *pleurapophysis,* or costal process, by the *parapophysis,* or lower transverse process, and by the *diapophysis,* or upper transverse process, which canal includes a vessel, and often also a nerve.

(1641.) Thus, a typical or perfect vertebra, with all its elements, presents four canals or perforations around a common centre; such a vertebra we find in the thorax of Man, and most of the higher classes of vertebrates, also in the neck of many birds. In the tails of most reptiles and mammals the inferior are articulated or anchylosed to the under part of the central elements, space being needed there only for the caudal artery and vein. But where the central organ of the circulation has to be lodged, an expansion of the hæmal arch takes place, constituting a thorax. Accordingly, in order to construct the thoracic cavity, the pleurapophyses (fig. 307) are much elongated, and the hæmapophyses (fig. 307) are removed from the centrum, and are articulated to the distal ends of the pleurapophyses, the bony hoop being completed by the intercalation of the hæmal spine (fig. 307) between the ends of the hæmapophyses. And this spine is here sometimes as widely expanded (in the thorax of Birds and Chelonians for example) as is the neural spine (parietal bone or bones) of the middle cranial vertebra of Mammals. In both cases also it may be developed from two lateral halves; and a bony intermuscular crest may be extended from the mid-line, as in the skull of the Hyena and the breast-bone of Birds.

(1642.) The ossified parts of the abdominal vertebræ of osseous Fishes answer to the centrum, the neurapophyses, the neural spine, the parapophyses, the pleurapophyses, and certain appendages to be hereafter noticed.

(1643.) In the air-breathing Vertebrata, in which the heart and breathing-organs are transferred backwards to the trunk, the corresponding osseous segments of the skeleton are in most instances developed in their typical completeness, in order to encompass and protect those organs. The thoracic hæmapophyses in the Crocodiles are partially ossified, and in Birds completely so, in which class the hæmal spines of the thorax coalesce together, become much expanded laterally, and usually develope a median crest downwards, to increase the surface of attachment for the great muscles of flight. This speciality is indicated by the namo " sternum," applied to the confluent elements in question.

(1644.) The typical thoracic vertebræ in Birds support *diverging appendages*, either anchylosed, as in most, or articulated, as in the *Penguin* and *Apteryx*, to the posterior border of the pleurapophysis. The function of such appendages in this form of typical vertebra is to connect one hæmal arch with the next in succession, so as to associate the two in action, and to give firmness and strength to the whole thoracic frame.

(1645.) The *diverging appendages* are, as might be expected, of all the elements of the vertebral segment, the least constant in regard to their existence, and the subjects of the greatest amount and variety of modification. Simple, slender spines or styles in Fishes (fig. 311, 13)—simple plates retaining long their cartilaginous condition in Crocodiles—short, flat, slightly-curved pieces in most Birds,—such, with one exception, is the range of the variety of form to which these parts are subject in the segments of the trunk. But that exception is a remarkable one, inasmuch as wo are enabled to trace the diverging appendage of that vertebral segment of the body, which from its form and character constitutes the pelvic arch, through various progressive phases of development —from that of a simple, articulated, solitary ray, such as exists in the *Lepidosiren*, through innumerable modifications, whereby it is adapted for swimming, steering, balancing, and anchoring—for exploration, for burrowing, creeping, walking, and running—for leaping, seizing, climbing, or sustaining erect the entire frame of the animal—under the general appellation of the posterior or pelvic limb.

(1646.) Any given appendage, however, as Professor Owen * justly observes, might have been the seat of such developments as convert that of the pelvic arch into a locomotive limb; and the true insight into the general homology of limbs enables us to point out many potential pairs in the typical endoskeleton. The possible and conceivable modifications of the vertebrate archetype are far from having been exhausted in the forms that have hitherto been recognized, from the primæval fishes of the palæozoic ocean of this planet up to the present time; or, in other words, it would be by no means contrary to tho general laws of osteogenic development, however different from the ordinary course of nature, were vertebrate animals to occur possessed of more than the two pairs of locomotive extremities usually conferred; so that such beings as hippogriffs and other winged quadrupeds, however fabulous, would be by no means monstrous productions.

(1647.) As the segments approach the tail in the air-breathing vertebrates, they are usually progressively simplified, first by the diminution, coalescence, and final loss of the pleurapophysis, next by the similar diminution and final removal of the hæmal and neural arches, and sometimes also by the coalescence of the remaining central elements, either into a long osseous style, as in the Frogs (fig. 333), or into a shorter flattened disk, as in many Birds. In Fishes, however, the seat of the terminal degradation of the vertebral column is first and chiefly in the central elements, which in the Homocercals, *i. e.* in those genera which, like the *Perch* (fig. 311), have a symmetrical bilobed tail, are commonly blended together, and shortened by absorption, whilst both neural and hæmal arches remain with increased vertical extent, and indicate the number of the metamorphosed or obliterated centrums.

(1648.) The anterior vertebræ of the spinal series are modified in their form and dimensions in proportion to tho increased development of the anterior part of the cerebro-spinal axis, and that to such an extent, more especially in the mammiferous races, that their real nature and character are completely masked from ordinary observation, nevertheless guided by the principles above laid down, that the bones of the cranial portion of the spinal column conform in their essential arrangement with what has been observed in the rest of tho vertebral series, and that the skull is in reality made up of the same elemental parts, modified, it is true, to a very remarkable extent, yet still recognizable, in accordance with just principles of philosophical induction, as the homologues of those described above.

(1649.) The cranial bones, when examined by any unprejudiced observer, readily resolve themselves into four distinct vertebræ, which may be named, reckoning them from behind forwards, the—

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* "On the Archetype and Homologies of the Vertebrate Skeleton." London: John Van Voorst.

Occipital, or Epencephalic ;
Parietal, or Mesencephalic ;
Frontal, or Prosencephalic
Nasal, or Rhinencephalic.

(1650.) The Occipital Vertebra, in the higher vertebrates, is represented by the occipital bone, in which all the vertebral elements are consolidated into one piece ; in the Reptilia, however, it is by no means difficult to identify the several parts which enter into its composition. They are as follows :—

Centrum	Basioccipital	5*
Neurapophyses	Exoccipital	9
Spine	Supraoccipital	8
Pleurapophyses	Paroccipital	10

The composition of the Parietal Vertebra is—

Parietal centrum	Basisphenoid	6
Neurapophyses	Alisphenoid.	
Spine	Parietal	7
Pleurapophyses	Mastoid	12

The Frontal Vertebra consists of—

Frontal centrum	Prosphenoid and Entosphenoid.	
Neurapophyses	Orbitosphenoid	14
Spine	Frontal	1
Pleurapophyses	Postfrontal	4

The Nasal Vertebra is composed of—

Nasal centrum	Vomer	16
Neurapophyses	Prefrontal	2
Spine	Nasal	20

(1651.) Thus far we are enabled to identify the cranial bones as being modified representatives of the spinal column, by allowing for that increased development of the neural elements here rendered necessary by the inordinate magnitude of the ganglionic centres of the cerebro-spinal axis ; but when we come to turn our attention to the constitution of the other portions of the chain, representing the lateral and inferior arches, or, in other words, the parapophysial and the hæmapophysial elements, together with the diverging appendages derived therefrom, the task becomes much more difficult. The labours of Professor Owen upon this interesting subject, unparalleled for depth of research, and exhibiting a grasp of philosophical argument rarely to be met with, have, however, satisfactorily revealed their real nature, and established beyond a

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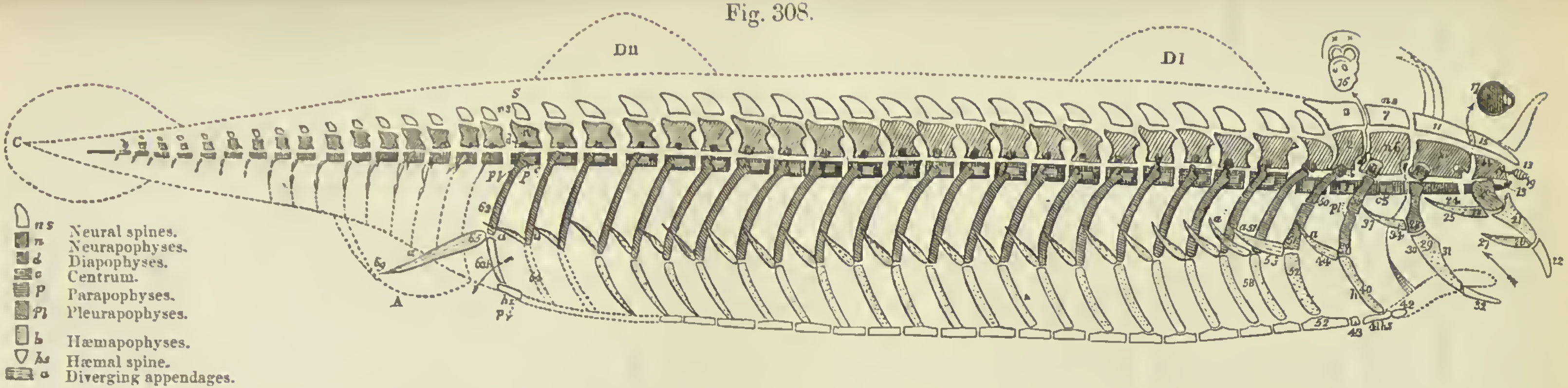
* These numbers correspond with those that indicate the individual bones of the cranium in subsequent figures.

Fig. 308.



Elements composing the typical vertebrate skeleton (after Owen).—The different elements of the primary segments are distinguished by peculiar markings: the neurapophyses by diagonal lines (*n*); the diapophyses by vertical lines (*d*); the parapophyses by horizontal lines (*p*); the centrum by decussating horizontal and vertical lines (*c*); the pleurapophyses by diagonal lines (*pl*); the hæmapophyses by dots (*h*); the diverging appendages by interrupted lines (*a*); the neural spines and hæmal spines are left blank.

The elements entering into the composition of the "archetype" are as follows:—1, basioccipital, or basilar; 2, exoccipital; 3, supraoccipital; 4, paroccipital—these constitute the occipital, or encephalic vertebra of the cranium; 5, basisphenoid; 6, alisphenoid; 7, parietal; 8, mastoid—completing the mesencephalic, or parietal vertebra; 9, presphenoid; 10, orbitosphenoid; 11, frontal; 12, postfrontal—forming the prosencephalic, or frontal vertebra; 13, vomer; 14, prefrontal; 15, nasal—composing the rhinencephalic, or nasal vertebra; 16, the petrosal, or acoustic sense-capsule, interposed between the occipital and parietal vertebræ; 17, the sclerotic, or ophthalmic sense-capsule, lodged in a cavity or orbit between the frontal and nasal vertebræ; 18, 19, ethmo-turbinal, or olfactory sense-capsule, situated immediately in advance of its proper segment, which becomes variously modified to enclose and protect it; 20, palatine; 21, maxillary; 22, premaxillary; 23, 24, 25, pterygoid; 26, malar; 27, squamous—constituting the hæmal arch of the nasal vertebra with its diverging appendages; 28, tympanic; 29–32, mandibular, or lower jaw; 34–37, operculars—composing together the hæmal arch of the frontal vertebra with its diverging appendages; the mouth opens in the interspace between the hæmal arches of the first and second segments, its place being indicated by an arrow; 38, stylohyal; 39, epihyal; 40, ceratohyal; 41, basihyal; 42, glossohyal; 43, urohyal; 44, branchiostegal—constituting the hæmal arch of the parietal vertebra with its diverging appendages; 50, suprascapula; 51, scapula; 52, coracoid; 52′, episternum; 53, anterior limb—completing the hæmal arch of the occipital vertebra with its diverging appendages; 58, clavicle, the hæmapophysis of the post-occipital vertebra; 62, ilium; 63, ischium; 65–69, posterior extremity—constituting the hæmal arch of the sacral vertebra (S), with its diverging appendages; 64, pubis, the hæmapophysis of one of the lumbar (?) vertebræ. Outlines of the chief developments of the dermo-skeleton in different vertebrates which are usually more or less ossified are added to the endoskeletal archetype: as, *e.g.* the median horn supported by the nasal spine (15) in the Rhinoceros; the pair of lateral horns developed from the frontal spine (11) in most Ruminants; the median folds (D 1, D 11) above the neural spines, one or more in number, constituting the "dorsal" fin or fins in Fishes and Cetaceans. Similar folds are sometimes developed at the end of the tail, forming a "caudal" fin, C, and beneath the hæmal spines constituting the "anal" fin or fins, A, of Fishes, and other analogous developments.

doubt the alliances which exist between the elaborate structures in question, and the arches which exist under simpler conditions appended to the vertebral segments of the trunk.

(1652.) From an extended survey of the organization of the skeleton throughout the vertebrate series, it is easy to perceive that, however diversified in adaptation to external circumstances, there is a general agreement between the various parts of the osseous framework, sufficient to convince us that all have been constructed in accordance with an ideal plan or archetype, from which ἰδέα, as Plato expresses it, the Creator has not deviated since the earliest appearance of the palæozoic races of VERTEBRATA up to the present period; and this "archetype" Professor Owen has illustrated by the diagram in the preceding page.

(1653.) The nervous system of the VERTEBRATA is by far more complex and elaborately organized than that of any of the four preceding divisions of the animal world, and consists, in fact, of several distinct systems, differently disposed, and appropriated to different offices. Certain largely-developed ganglia, situated in the cavity of the cranium, generally considered by themselves on account of their disproportionate size when compared with the other nervous centres, are commonly grouped together under one common designation, and form what is called the *brain*, or *encephalon*: these masses, however, as we shall hereafter see, preside over various and widely-different functions, and with them perception, volition, and intelligence are essentially connected.

(1654.) Continued from the *brain*, and lodged in a canal formed by the superior arches of the vertebral column, is a long chain of ganglionic centres, so intimately united that they appear confused into a long medullary cord, usually denominated the *spinal marrow* (*medulla spinalis*).

(1655.) The spinal medulla in reality consists of two double series or *columns*, composed of symmetrical and parallel ganglia,—one pair of columns, the anterior, presiding over those muscular movements which are under the control of the will, while the posterior are destined to receive impressions derived from the exterior of the body; these columns, therefore, are denominated respectively the motor and sensitive tracts of the spinal cord.

(1656.) From the lateral aspects of the medulla spinalis are derived, at intervals, symmetrical pairs of nerves, which escape from the spinal canal by appropriate orifices situated between the different bones of the vertebral column, and are distributed to the voluntary muscles and integument of the two sides of the body.

(1657.) The spinal nerves, however, are not so simple in their composition as they were considered to be by the older anatomists: each of them has, in fact, been found to arise from the spinal cord by two distinct roots, one derived from the anterior, the other from the posterior column of the corresponding side; so that each nerve is evidently made up of two distinct sets of filaments, one set communicating with the motor, the other with the sensitive tracts; and thus every nerve derived from the spinal cord is a compound structure, being composed of filaments distinct in office, although enclosed in the same sheath, some being connected with the muscular movements, the others with sensation. But in addition to the cerebro-spinal ganglia and the symmetrically-arranged nerves emanating therefrom, that are distributed to the organs of sensation and movement, there exists in the VERTEBRATA a distinct system of nervous centres lodged among the viscera, appropriated to the performance of the automatic functions, and presiding over those involuntary movements of the body upon which depend the operations connected with nutrition. These ganglia are variously distributed, being situated in the head, the neck, the thorax, and the abdomen; and from them arise large plexuses of nerves, destined to supply the organs belonging to digestion, circulation, and secretion,—thus forming extensive ramifications, formerly distinguished by the name of the *sympathetic nerve*, but now more properly considered as a distinct system presiding over *organic life*, as the former is connected with the phenomena of *animal life*.

(1658.) With the increased development of the nervous system in the vertebrate classes we find the organs of the senses assume a proportionate perfection of structure and regularity of arrangement. The auditory apparatus, of which we have seen only rudiments in the lower animals, gradually becomes more and more elaborately organized. The eyes, now invariably two in number, are lodged in cavities formed for their reception by the osseous framework of the face, and exhibit, in the simplicity of their structure, a higher type of organization than any we have hitherto examined. Organs of smell, also double, but of very variable construction, are likewise constantly present. The tongue becomes slowly adapted to appreciate and discriminate savours; and the sense of touch, the most generally diffused of all, is especially conferred upon organs of different kinds peculiarly adapted to exercise this faculty. Thus with increased intelligence higher capabilities of enjoyment are allotted, and sagacity developes itself in proportion as the nervous centres expand. But there are minor points, characteristic of the vertebrate division of the animal world, which must not be omitted in this preparatory survey of their organization. Their organs of digestion and nutrition are constructed according to a different type, and upon a more enlarged plan than in any of the classes enumerated in the preceding chapters; and parts are superadded to the digestive apparatus which in lower tribes had no existence. In addition to the usual subsidiary glands, namely, the salivary and the hepatic, a third secretion is poured into the intestine along with the bile, derived from the *pancreas*, a viscus which we have not as yet met with. Throughout all the MOLLUSCA we have found the bile secreted by the liver to be separated from arterial blood, as are the other secretions of the body; but in the VERTEBRATA it is from venous blood that the bile is formed, and in consequence an elaborate system of vessels is provided, distinct from the general circulation, by which a large supply of deoxygenized blood is conveyed to and distributed through the liver, constituting what is termed by anatomists the system of the *vena portæ*: nay, more, in connexion with this arrangement we find another remarkable viscus make its appearance, the *spleen*, from which venous blood is copiously supplied to the portal vein, and added to that derived from other sources.

(1659.) A still more important and interesting circumstance, which strikes the anatomist on comparing the Vertebrata with lower forms of existence, is the sudden appearance of an entirely new system of vessels, destined to absorb from the intestines the nutritious products of the digestive process, and to convey them, as well as fluids derived from other parts of the body, directly into the veins, there to be mixed with the mass of the circulating blood. These vessels, of which no traces have been detected in any of the Invertebrata, are called *lymphatics* and *lacteals*; but their structure and distribution will occupy our attention hereafter.

(1660.) The blood of all the Vertebrata is red, and is composed of microscopic globules of variable form and dimensions in different animals. In the class of Fishes, owing to the as yet imperfect condition of the respiratory apparatus, the temperature of the body is scarcely higher than that of the surrounding medium; and even in Reptiles such is the languid condition of the circulation, and the incomplete manner in which the blood is exposed to the renovating influence of the oxygen derived from the atmosphere, that the standard of animal heat is still extremely low. But in the higher classes, the Birds and Mammalia, owing to the total separatiou of the systemic and pulmonary circulation, the effect of respiration is increased to the utmost; and, pure arterial blood being thus abundantly distributed through all parts, heat is more rapidly generated, the warmth of the body becomes considerably increased, and such animals are permanently maintained at an invariable temperature, considerably higher than that of the medium in which they live. Hence the distinction generally made between the hot-blooded and cold-blooded Vertebrata.

(1661.) The variations in the temperature of the blood, above alluded to, are, moreover, the cause of other important differences observable in the clothing, habits, and instincts of these creatures. To retain a high degree of animal heat necessarily requires a warm and thick covering of some non-conducting material; and consequently in the hair, wool, and feathers of the warm-blooded tribes we at once recognize the provision made by Nature for preventing an undue expenditure of the caloric generated in the body. Such investments, however, would be ill adapted to the inhabitants of a watery medium; and consequently the fish, destined to an aquatic life, and the amphibious reptile, doomed to frequent the mud and slime upon the shores, are deprived of such incumbrances, and clothed in a scaly or slippery covering more fitted to their habits, and equally in accordance with the diminished temperature of their blood.

(1662.) Still more remarkable is the effect of a mere exaltation of animal heat upon the instincts and affections of the different races of the VERTEBRATA. The fishes, absolutely unable to assist in the maturation of their offspring, are content to cast their spawn into the water, and remain utterly careless of the progeny to be derived from it. The reptile, equally incapable of appreciating the pleasures connected with maternal care, is content to leave her eggs exposed to the genial warmth of the sun until the included young escape. But no sooner does the vital heat of the parent become sufficient for the purposes designed by Nature, than all the sympathies of parental fondness become developed, all the delights connected with paternity and maternity are superadded to other enjoyments; and the bird, as she patiently performs the business of incubation, or tenderly watches over her newly-hatched brood, derives a pleasure from the performance of the duties imposed upon her, second only to that enjoyed by the mammiferous mother, who from her own breast supplies the nutriment prepared for the support of her infant progeny.

CHAPTER XXVI.

PISCES—FISHES.

(1663.) To whatever portion of the animal world we turn our attention, we find the lowest and least-perfectly organized tribes to be inhabitants of the water. To dwell upon the land necessarily demands no inconsiderable share of strength and activity—limbs sufficiently strong to support the weight of the body, muscles possessed of great power and energy of action, acute and vigilant organs of sense, and, moreover, intelligence and cunning proportioned to the dangers or necessities connected with a terrestrial existence.

(1664.) The inhabitant of the waters, on the contrary, although less highly gifted, may be fully competent to enjoy the position it is destined to occupy. Being constantly buoyed up on all sides by a dense element, it is easily supported at any required altitude without much muscular effort; but feeble limbs are needed to guide its path through the water, and slight impulses suffice to impel it forward. Thus, therefore, in Fishes we are prepared to expect, *à priori*, that, as far as strength and compactness of structure are concerned, they will be found inferior to other Vertebrata.

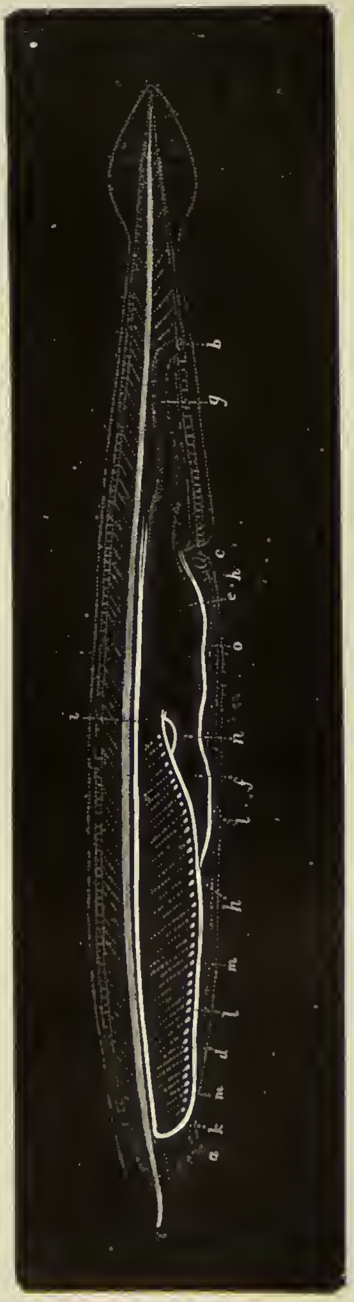
(1665.) We are likewise justified in anticipating that, in intelligence, and in the relative perfection of their senses, Fishes should be less highly endowed than the other vertebrate classes. Plunged in the immeasurable depths of the ocean, whereunto no sound can ever penetrate—dwellers in the realms of eternal silence, where even the roar of the storm is lost, vivid and distinct perceptions of sound can be little needed. Surrounded by a turbid element, through which the rays of light with difficulty make their way, the sphere of vision must necessarily be extremely limited. Immersed in a fluid but little adapted to distribute odorous particles, a refined sense of smell would be a useless provision. Taste, if it exists at all, must be blunted to the utmost, from the circumstances under which fishes seize and swallow prey; and even the sense of touch, in animals encased in scales and deprived of prehensile limbs, can only be exercised in a vague and imperfect manner.

(1666.) With such inferiority in their powers of communication with the external world, and with faculties so circumscribed, we might justly infer that, as relates to their intellectual powers, Fishes hold a position equally debased and degraded. Destitute of the means of social intercourse, deprived of all sympathy even with individuals of their own species, friendless and mateless, the fish is denied even the privileges of sexual attachment; the female for the most part ejects her countless eggs into the sea, as heedless of the male that blindly fecundates them as she is careless of the progeny to which they give birth. Thus, to pursue and destroy their prey constitutes their chief enjoyment during life, and to be devoured at last is the great end of their existence.

(1667.) We shall commence our account of the anatomy of FISHES by an examination of the internal skeleton which forms the framework of their bodies. The reader has already seen, in the Cephalopoda, the first appearance of an osseous system in the cartilaginous pieces described in the last chapter, and will necessarily expect that, between the rudimental condition which characterizes the cephalic ring of the Cuttle-fish, and the complete and perfect skeleton of the Fish, various gradations of development will occur as we advance progressively from lower to more elevated forms of the finny race. Nor in this will he be deceived. The lowest tribes of Fishes possess a skeleton but little superior in its organization to that of theCephalopod: in the *Myxine* and *Lamprey* the cranium is still cartilaginous; and even the spinal column, not yet divided into vertebræ, resembles a cartilaginous cord extending from the head to the tail. Even in the *Sturgeon*, the *Skate*, and the *Shark*, the skeleton is but very partially ossified; and thus we are gradually and almost imperceptibly conducted to the strong and bony framework of the typical Fishes.

(1668.) But the most curious instance of gradation between the true Fishes and the Mollusca is met with in the *Amphioxus*. The Amphioxus is met with in all the European seas, but is more especially abundant in the Mediterranean. Its usual residence is upon banks of sand, where it finds both shelter and abundance of nourishment. Like the Ascidians, it seems to feed entirely upon infusorial organisms, either animal or vegetable, which abound in the localities that it frequents, and which it swallows, just as the Ascidians do, by the instrumentality of the vibratile cilia with which its mouth and branchial chamber are richly provided. Such is the activity of its movements, that, when dug up from its hiding-place in the sand, if left loose for a single instant, it buries itself again with astonishing rapidity, and thus almost instantaneously eludes the grasp of those who attempt its capture. Although decidedly a member of the vertebrate series of animals, the Amphioxus can hardly be said to possess a skeleton, so soft is the condition of those tissues which, from their arrangement, evidently represent this structure; still it is not difficult to point out the arches of the lower jaw (fig. 309, *a*) and of the branchial apparatus (*d*), as well as the structure and position of the spinal column.

Fig. 309.



Amphioxus.

(1669.) One of the most interesting features in the anatomy of the *Amphioxus* is, that the canal which encloses the medulla spinalis presents anteriorly no cranial expansion, but the dorsal cord representing the spine extends quite from one extremity of the body to the other, projecting both behind and before considerably beyond the lateral muscles of the body, and extending anteriorly considerably further forward than the oral apparatus (*a*), or the anterior termination of the spinal cord.

(1670.) The mouth (fig. 309) is surrounded by a cartilaginous ring, composed of several pieces, each of which gives off a prolongation to support the cirri that surround the oral orifice. The buccal cavity is lined with mucous membrane, and is densely ciliated,—the ciliary action forcing continuous currents of water towards the branchial chamber (*d*), or the branchial canal, as it is called by Müller, which, being continued backwards, terminates in the commencement of the alimentary canal (*e*).

(1671.) The branchial chamber is supported by a very singular sort of framework, first described by Retzius and Goodsir, and subsequently more in detail by Professor Müller. It consists of a considerable number (variable according to the age of the animal) of thin rib-like processes, which are united together superiorly, but quite free below, so that they constitute a series of semicircular arches, united together by transverse cartilaginous bands, so as to roof-over the branchial vault. This solid framework is lined internally with a kind of mucous membrane, which, however, is not continuous from rib to rib, and consequently does not fill up the intercostal spaces, but leaves a fissure between each pair of the cartilaginous arches, so that in adult specimens there are as many as a hundred of these branchial fissures or more; nevertheless, as the whole branchial chamber, as well as the margins of these fissures, which are extremely narrow, are closely set with vibratile cilia, it is very difficult to perceive their existence, which, indeed, was denied both by Rathke and Goodsir.

(1672.) On placing a living Amphioxus in water coloured with indigo, and observing it with a microscope, it is apparent that the coloured particles that enter the branchial chamber are driven by the ciliary action, partly towards the alimentary canal, and enter the intestine, while another part traverse the branchial fissures, and thus enter the abdominal cavity, where there is no longer any ciliary movement, but the water which flows into it unceasingly through the branchial apparatus forms a continuous current, which finds an exit through the *abdominal pore* (*c*), the margins of which exhibit ceaseless movements of contraction and dilatation. Behind the abdominal pore, the cavity of the abdomen is impermeable to water, and closely embraces the terminal portion of the intestine.

(1673.) The cavity in which the branchial apparatus above described is lodged contains likewise the greater portion of the alimentary tube, as well as the liver, the generative apparatus, and the kidneys; so that, in fact, it performs the functions both of a respiratory and abdominal cavity.

(1674.) The digestive system of this singularly-organized being presents, in many respects, a very degraded type of structure. The branchial chamber above described terminates posteriorly in a short and narrow canal, which is the œsophagus. This opens into a wider intestine, which is always easily distinguishable, owing to the green colour of its parietes. A little beyond the termination of the œsophagus, there is appended to the intestine a long cæcum (*f*), almost as capacious as the intestine itself, which is supposed by some to represent the liver, here reduced to its simplest possible condition. Müller, however, adds that the whole of the intestinal walls, which are lined with a greenish glandular structure, may be regarded as performing the functions of a hepatic organ.

(1675.) The whole track of the intestinal tube, as well as the (so-called) hepatic viscus, is covered internally with vibratile cilia. The ciliary action, however, is more especially conspicuous in that part of the intestine which lies beyond the green-coloured portion ; and it is here that excrementitious matter begins to be formed, which may be observed turning round and round with velocity in consequence of the surrounding ciliary movement.

(1676.) At the posterior part of the respiratory chamber, and close to the abdominal pore, the microscope displays some small detached glandular bodies, which Müller thinks may be the kidneys ; he, however, remarks that he could never discover them by dissection.

(1677.) The ovaria consist of lax cellular tissue, surrounded with a delicate but strong membrane, which is closed on all sides. They are adherent by one side to the walls of the abdominal or, rather, thoraco-ventral cavity ; elsewhere they are covered by the peritoneum. Costa, who first recognized these organs, observed that in the males the testes occupied the same situation as the ovaria. There are neither oviducts nor vasa deferentia ; so that the products of the generative organs must necessarily pass through the abdominal cavity and escape through the abdominal pore, as is the case among the cyclostomous cartilaginous fishes.

(1678.) The description given by Müller of the circulation of the blood in the *Amphioxus* is extremely interesting. The circulatory apparatus, while presenting a considerable resemblance to the normal arrangement met with in other fishes, exhibits an equally strong analogy with that of some of the Annelida in its division and distribution.

(1679.) Müller enumerates *, as belonging to the circulatory apparatus of *Amphioxus*, the following parts :—1. the arterial heart (*das Arterienherz*) ; 2. the bulbs of the branchial arteries (*die Bulbillen der Kiemenarterien*) ; 3. the aortic arch, which discharges the functions of a systemic heart (*der herzartige Aortenbogen*) ; 4. the heart of the vena portæ (*das Pfortaderherz*); 5. the heart of the vena cava (*das Hohlvenenherz*),—the duties assignable to each being as follows :—The arterial heart (fig. 309, *l l*) is a thick vessel of uniform calibre throughout, situated in the median line, and running immediately beneath the branchial chamber, between the arches forming the framework of that cavity ; posteriorly this vessel is continuous with the heart of the *vena cava* (*n*). Before the moment of contraction, the arterial heart is seen to be filled with perfectly colourless blood ; but when fully contracted, it is completely emptied (the interval between its contractions is about a minute). From its sides are given off the *bulbs of the branchial arteries*

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* "Ueber den Bau und die Lebenserscheinungen des *Amphioxus lanceolatus*." Berlin Trans. 1842.

(fig. 309, *m m*), which are little contractile cavities situated at the commencement of each branchial vessel, forming so many little hearts accessory to the preceding. Their number varies with that of the branchial arches, from five-and-twenty to fifty on each side, their office obviously being to distribute unrespired blood through the branchial apparatus. No branchial veins can be distinguished in the living animal; but by carefully detaching the branchial chamber and laying it on a strip of glass, it becomes apparent that the aorta, situated upon the dorsal aspect of the respiratory cavity, receives the veins supplied from each branchial arch.

(1680.) *Aortic arch performing the functions of a heart.*—The blood of the Amphioxus is not, as in fishes, entirely supplied to the aorta through the medium of the branchiæ, but is partly conveyed immediately into that vessel through two large trunks, the representatives of the *ductus arteriosus* (fig. 309, *k*), which directly unite the median arterial heart with the aorta, and are, to a certain extent, continuations of the heart itself. They are, however, themselves contractile organs, and are actively employed in the propulsion of the blood, as is the aorta itself (fig. 309, *i*), which, doubtless, performs the functions of a heart.

(1681.) The *heart of the vena portæ* (fig. 309, *o*) is a long vessel, which runs along the under surface of the intestine as far as the hepatic cæcum; its contractions are readily observable in the living animal, the intervals between each being exactly the same as in the other hearts above mentioned.

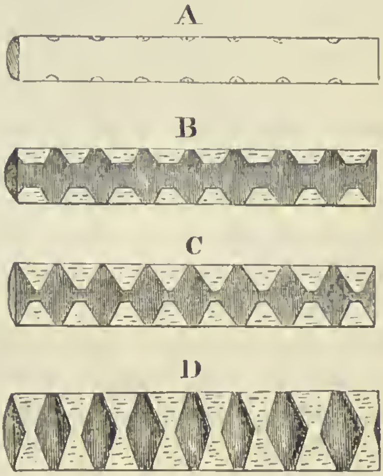
(1682.) The *heart of the vena cava* (fig. 309, *n*) is placed opposite to the preceding—that is to say, on the dorsal aspect of the hepatic cæcum: it is at first of small size, but gradually becoming larger, ultimately empties itself into the arterial heart (*l*), which it supplies with blood.

(1683.) The contractions of the vessels, or hearts, above described succeed each other in such a manner that each in turn becomes gradually filled, while others contract. The systole of the arterial heart does not commence before the act of contraction has been completed in all the rest of the system. Moreover each trunk contracts in succession with so much energy that it seems to empty itself entirely, and remains for some little time undistinguishable, from which circumstance it necessarily results that any given portion of the blood will have passed through the entire round of the circulation in the time which elapses between the consecutive contractions of the same portion of the vascular system—a space of time which observation shows to be in *Branchiostoma* about a minute.

(1684.) But, perhaps, the most remarkable feature in the anatomy of this singularly-organized being is the apparently complete absence of a brain. The medulla spinalis, slightly thickened towards the central part of the body, tapers off posteriorly as it approaches the tail, where it terminates in a point; and towards the anterior part of the body, as appeared to MM. Rathke* and Goodsir†, a similar disposition was observable: hence they conceived that the central axis of the nervous system in this fish was reduced entirely to the parts representing the spinal cord in other Vertebrata. Subsequent researches have, however, shown that this is not strictly the case, but that, although there is no cerebral enlargement corresponding to the encephalon of ordinary fishes, the anterior extremity, inasmuch as there exist distinct olfactory ‡ and optic organs, must be regarded as essentially encephalic in its nature.

(1685.) In tracing the modifications observable in the construction of the vertebral column of fishes, we have a beautiful illustration of the progressive advances of ossification in this the central portion of the osseous system. The spine of the Lamprey, although at first sight apparently entirely soft and cartilaginous, presents already, in the arches which compose the spinal canal, and in the soft cord that represents the bodies of the vertebræ, slight indications of an incipient division into distinct pieces: rings of ossific matter are distinguishable, encircling at intervals the soft spinal cartilage, upon which they perceptibly encroach; so that, on making a longitudinal section of the cord, it offers the appearance sketched in the adjoining figure (fig. 310, A). In a more advanced form of a fish's skeleton, as for example in the Sturgeon, these ossified rings are found to have enlarged considerably, and penetrate still more deeply into the cartilaginous mass (fig. 310, B). As the bony rings thus developed approximate the centre, it becomes more and more evident that they represent the bodies of so many vertebræ; but even in the majority of fishes the central part remains permanently unossified, so that a cartilaginous axis traverses the vertebral column from one end to the other (fig. 310, C); and it is not unusual to find the central aperture perfectly obliterated, as delineated in the fourth sketch (D).

Fig. 310.



Development of vertebral column.

(1686.) Fishes, being continually resident in an element nearly of the same specific gravity as their own bodies, require little firmness or solidity in the construction of their spinal column: a free and unfettered power of flexion in certain directions, so as to permit an ample sweep of their expanded tail, which forms the principal agent in propelling them forwards, is far more essential to their habits. Thus the cartilaginous spine of the feeble Lamprey is sufficient for all needful purposes; and even in the most perfectly ossified fishes, from the manner in which the vertebræ are united to each other, the greatest possible flexibility is ensured. The body of each vertebra presents two conical cups, the apices of which are nearly or quite continuous; the margin of each cup-like depression is united by elastic ligament to the corresponding margin of the contiguous vertebra, and thus between the bodies of each pair of vertebræ a wide cavity is formed (fig. 310, D), which is filled up with a semigelatinous substance; so that, by this beautiful contrivance, the mobility of the whole chain is abundantly provided for.

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* "Bemerkung über den Bau des *Amphioxus lanceolatus.*" Monatsberichte der Akad. der Wissenschaften, 1841.

† Transactions of the Royal Society of Edinburgh, vol. xv.

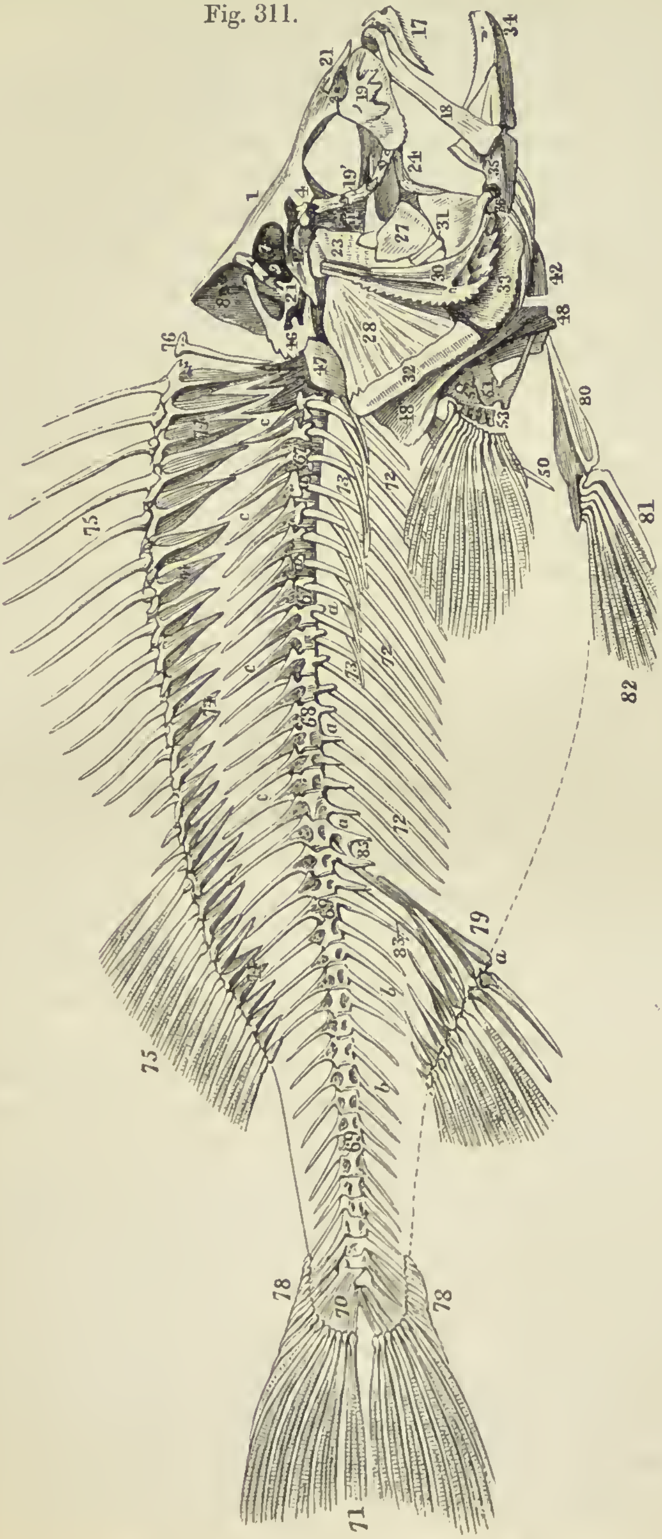
‡ *Vide* Kölliker, Müller's Archiv, 1843.

(1687.) There are only two kinds of vertebræ recognizable in the skeleton of a Fish, viz. the abdominal and the caudal. The abdominal vertebræ support the ribs (for in these animals the ribs do not constitute a thorax, or contain any of the viscera called thoracic in the human body); they extend from the head to the commencement of the tail, and are at once recognizable by the nature of the elements which enter into their composition, each vertebra being provided with a *superior arch* (fig. 306, *b*), through which passes the spinal cord, a *superior spinous process* (*c*), and two *transverse processes* (*d*), to the extremities of which the ribs are generally attached. The caudal vertebræ are composed, as we have already seen, of different elements: the transverse processes either do not exist, or are very feebly developed; but beneath the body an *inferior arch* is formed, and from this an inferior spinous process, equalling the superior in length, is prolonged in the opposite direction (fig. 311, *b*).

(1688.) As the vertebræ approach the tail, they become somewhat modified in structure to support the caudal fin; their spines become shorter and thicker, the canals formed by their superior and inferior arches smaller or nearly obliterated, and at length the spines become, as it were, soldered to each other and to the interspinous bones hereafter to be noticed; so that they form a broad vertical plate, to the posterior margins of which the rays of the tail-fin are articulated (fig. 311, 70).

(1689.) The *ribs* of Fishes are slender bones, appended either to the extremities of each transverse process of the abdominal vertebræ, or else to the body of the vertebra itself: every rib is connected with but one vertebra, and that only at a single point. They do not, as we have already said, form a thoracic cavity, but enclose the abdomen, and are imbedded among the lateral muscles of the trunk, to which they give support. From each rib arises a long styliform process (73), which, inclining backwards, is likewise plunged among the muscular fasciculi; and in some fishes, such as the Herring and Carp tribes, similar appendages are derived from the bodies of the vertebræ themselves, so that the bones of such fishes appear to be extraordinarily numerous. On the other hand, many tribes have but the rudiments of ribs; and in some, as, for example in the Skate, they are altogether wanting.

Fig. 311.



Skeleton of the Perch (*Perca fluviatilis*). (After Cuvier.)

(1690.) No *sternum*, properly so called, exists in Fishes; but the extremities of the ribs are sometimes connected with ossified plates belonging to the tegumentary system, which cover the abdomen, and which by some authors have been regarded as a sternal apparatus.

(1691.) We have now to request the attention of the reader to certain supplementary organs which are peculiar to the class before us. These consist in sundry appendages to both the superior and inferior spinous processes of the vertebræ, which are generally prolonged into fins situated along the mesial line of the body. These single fins, which must by no means be confounded with the pairs of fins that represent the arms and legs, are very variable in their position, and in many cases are altogether wanting. When fully developed, one of them is situated along the mesial line of the back, and in the Perch (fig. 311) this *dorsal fin* is separated into two distinct portions (75); another, denominated the *caudal fin*, forms the tail; and a third, likewise situated in the median line, at a short distance behind the anal orifice, is called the *anal fin* from that circumstance.

(1692.) These fins present two sets of bones—the *interspinous bones*, which form the basis to which they are affixed, and the *fin-rays*.

(1693.) The *interspinous bones* (fig. 311, 74) form a series of strong dagger-like bones, deeply implanted in the flesh along the mesial line of the body, between the two great masses of lateral muscles: their points generally penetrate to a little distance between the spinous processes of the vertebræ, to which they are connected by a ligamentous attachment; whilst to their opposite extremity, which may be compared to the hilt of the dagger, the corresponding fin-rays are affixed by a beautiful articulation. There is generally only one interspinous bone affixed to a vertebral spinous process, but in the Flat-fishes (*Pleuronectidæ*) there are two; and moreover, in that remarkable family, the inferior spinous process of the first caudal vertebra (which, as we have already seen, is of enormous size) frequently has not fewer than six or seven interspinous bones appended to its extremity.

(1694.) Each interspinous bone consists of two pieces, united by a suture,—one portion representing the blade, the other the handle of the dagger, to which we have compared it.

(1695.) The fin-rays of Fishes are of two kinds, being either solid, and apparently composed of one strong piece, like those which support the anterior half of the dorsal fin of the *Perch* (75), in which case they are called *spinous rays*, or else they are composed of several slender stems derived from one common root, every one of which is made up of numerous pieces: these, which bear the name of *soft rays*, are found in the posterior portions both of the dorsal and anal fin of the Perch, and are invariably met with in the tail of all fishes possessed of a caudal fin. This difference in the structure of the fin-rays, trivial as it might appear, is a circumstance to which much importance is attached by ichthyologists.

who hence derive the means of separating osseous fishes into two great groups—the *Acanthopterygii*, or such as possess spinous rays in the composition of their dorsal fin, and the *Malacopterygii*, in which all the fin-rays are soft. Every fin-ray, whether spinous or soft, is in reality made up of two lateral halves placed side by side: in the soft rays these are easily separable; but in the spinous rays they are firmly united along the median line, so as to represent but one bone.

(1696.) The articulation between every fin-ray and the corresponding interspinous bone forms a hinge-joint, so as to allow of the elevation or depression of the fin. The structure of this joint is very beautiful: the two lateral halves of the ray separate, so as to form two branches, which firmly embrace the sides of the head of the interspinous bone, and terminate in little prominent tubercles which are received into corresponding lateral depressions in the bone to which the ray is attached. Sometimes, indeed, the head of the interspinous bone is completely perforated, and then the two branches of the fin-ray passing through the opening become firmly united with each other, forming a kind of joint which is peculiar to Fishes, and exactly resembles the mode of union between two links of a chain. This structure is beautifully exhibited in the articulation of the elongated rays attached to the head of *Lophius piscatorius**.

(1697.) The composition of the skull of Fishes is one of the most difficult studies connected with their history; nevertheless it is a subject of very considerable importance, and has recently occupied the attention of the most celebrated Continental anatomists. It is not by any means our intention to engage our readers in discussing all the conflicting, and sometimes visionary, opinions entertained by different authors relative to the exact homology of the individual bones forming this part of the skeleton; and we shall therefore content ourselves by placing before them, divested as far as possible of superfluous argumentation, Cuvier's† masterly analysis of the labours of the principal inquirers concerning this intricate piece of anatomy, taking the Perch as a standard of comparison‡.

(1698.) The head of a Fish may be conveniently divided, for the purpose of description, into several distinct regions, each of which will require separate notice.

(1699.) The *cranium*, which forms the central portion of the skull, contains the brain and auditory apparatus, and constitutes the basis whereunto the other parts are connected. It is remarkable from the number of distinct pieces of which it consists, inasmuch as in Fishes the elements, or ossific centres, of which the cranial bones of higher animals are composed remain here permanently separated, overlapping each other, so as to form squamous sutures, but never becoming fused together, as the elements of the human skull invariably do at a very early period.

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* *Vide* Yarrell's History of British Fishes, vol. i. p. 271. 8vo.

† Cuvier et Valenciennes, Histoire des Poissons, vol. i. 4to.

‡ Those who would enter more fully into the discussions relative to the essential composition of the skull are referred to the works of Geoffroy St.-Hilaire, Spix, Rosenthal, Meckel, Bakker, Bojanus, and Oken, the great disputants upon this subject.

(1700.) No fewer than twenty-six bones enter into the composition of the cranium we are now considering; to which, as is now generally allowed, the following names are applicable.

(1701.) The frontal bones are each divided into three portions, called respectively the *principal frontal* (1)*, the *anterior frontal* (2), and the *posterior frontal* (4).

(1702.) Between the anterior frontal bones is the *ethmoid*, a simple vertical lamella, which is often merely a cartilaginous plate.

(1703.) The middle of the base of the cranium is made up of two bones:—the *basilar* (fig. 312, 5), a portion of the occipital, forming the body of the occipital vertebra; and the *body of the sphenoid* (6), a distinct bone, which is prolonged anteriorly into a lengthened process, which serves as the base of the membranous septum between the orbits.

(1704.) The *parietal bones* (7) are placed behind the posterior frontal; but they do not generally touch each other, being separated by an interposed bone called the *interparietal* (8).

(1705.) The occipital bone is made up of five portions: namely, two *external occipitals* (9), two lateral occipitals (10), and the basilar bone (5), already noticed, by which the head is articulated with the first vertebra of the spine.

(1706.) Two detached bones, which represent the *great* or *temporal alæ of the sphenoid*, fill up the space between the body of the sphenoid and the posterior frontal.

(1707.) Two other pairs of bones, which are elements of the temporal bone in Man, likewise assist in forming the cranium: these are called the *mastoid bones* (12) and the *petrous bones* (13).

(1708.) A single bone, analogous to the anterior portion of the body of the human sphenoid, and which, as will be fully evident hereafter, is essentially distinct from the posterior portion, bears the name of the *anterior sphenoid*, while the *orbital alæ of the sphenoid* are found in the two bones marked 14.

(1709.) These, therefore, together with the representative of the *vomer* (16), complete the cranial portion of the skull; no fewer than six azygos and twenty pairs of bones entering into its composition.

(1710.) *Bones composing the upper jaw.*—The upper jaw consists of two pairs of bones, which, from the looseness of their connexion with the other bones of the face, are endowed with considerable mobility.

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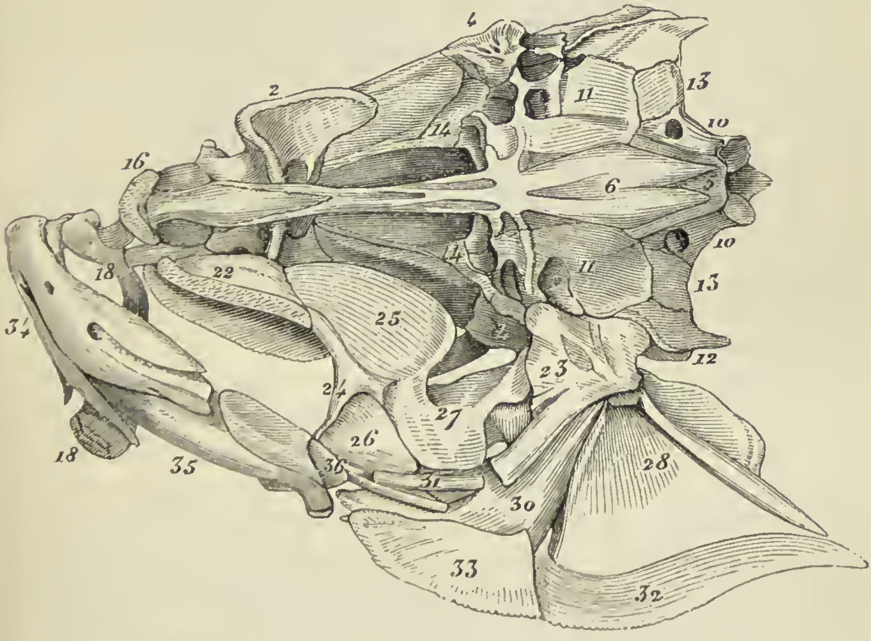
* In order to simplify the subject as much as possible and prevent unnecessary repetition, the reader will observe that, throughout all the figures connected with the osteology of the Vertebrata, *corresponding bones are indicated by the same numbers.*

(1711.) The *Intermaxillary bones* (17) form the greater part of the margin of the jaw, and are attached by a moveable articulation to the anterior extremity of the vomer. These bones are armed with numerous sharp teeth.

(1712.) The *maxillary bones* (18) are moveably articulated with the last, and generally are in like manner furnished with teeth. In some cases they are divided into two or three pieces.

(1713.) *Bones of the face.*—The bones of the face in Fishes are very numerous; but, as they are of little importance to the osteologist, a bare enumeration of them will answer our present purpose, and enable the student to recognize them with facility. We have first the *nasal bones* (20); then a chain of bones of variable size and number (19), so disposed as to form the lower boundary of the orbit, and hence named *suborbital bones.* Behind these, again, a similar chain of ossicles is not unfrequently met with, arching over the temporal fossa; and these, which are apparently peculiar to Fishes, are named the *supratemporal* (21).

Fig. 312.



Cranial and facial bones of the Perch: basilar view. (After Cuvier.)

(1714.) *Pterygo-palatine and temporal system of bones.*—Upon each side of the head is situated a somewhat complex apparatus, connected on the one hand with the articulation of the lower jaw, and on the other with the opercula, or gill-covers. These bones are seven in number on each side.

(1715.) The *palatines* (22) are easily recognizable, forming part of the roof of the mouth, and generally armed with teeth.

(1716.) Two bones are connected with the posterior edge of each palate bone: one, situated externally, becomes, in Reptiles, a very important element; it is called the *transverse bone* (24); the second (25) is named the *internal pterygoid.*

(1717.) The other pieces belonging to this part of the skeleton are not a little interesting on account of their remarkable arrangement; and perhaps the anatomical student will be somewhat startled at the position which some of them occupy. In the first place, the squamous portions of the temporal, instead of entering into the formation of the cranium, are here slightly displaced, and, although still called the *temporal bones* (23), are articulated by a hinge-joint with the posterior frontal and mastoid bones, and thus form a moveable basis to which the opercular apparatus is attached.

(1718.) Connected with the *temporal* we have the broad and flat piece, 27, which is the *tympanic bone*; and to these the pieces forming the opercula are appended.

(1719.) Lastly, supporting the lower jaw we find the *jugal bones*; and connecting these with the rest of the temporal apparatus are two small ossicles (31), which complete this portion of the skeleton.

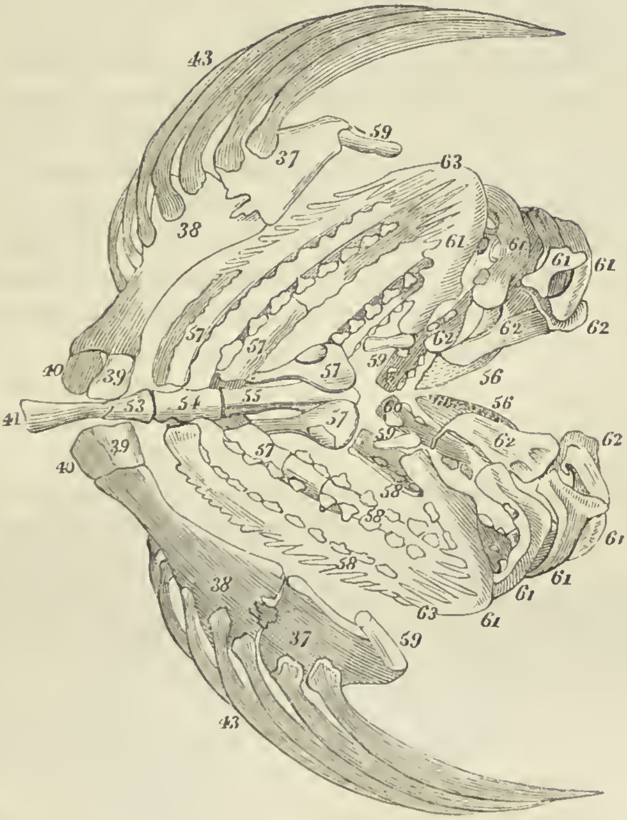
(1720.) The seven bones above enumerated are almost immoveably connected with each other by the interposition of cartilage between their edges—a mode of articulation distinguished by the name of *synchondrosis*; but the whole apparatus moves readily upon two hinges, one formed by the articulation of the palate bone with the maxillary and vomer, and the other by the joint which unites the temporal bone to the posterior frontal. This movement, by opening the gill-covers, enlarges the cavity of the mouth when the fish wishes to take in the water necessary for respiration, or else, by acting in a contrary direction, again expels it.

(1721.) *Opercular bones.*—The great flap, which in osseous fishes closes the gill-openings externally, is composed of four pieces, to which the following names have been given. The *præoperculum* (30) is attached to the posterior edge or angle of the palato-temporal apparatus last described, and its borders often present spines and indentations, which, being visible externally, are of much importance to the ichthyologist, as they afford a good character of distinction between allied genera. The second piece (28), which from its size is called *par excellence* the *operculum*, together with the *suboperculum* (32) and the *interoperculum* (33), form a flap which covers the gill-opening like a great valve, opening and shutting continually to give exit to the water used in respiration.

(1722.) *Lower jaw.*—The lower jaw of Fishes consists of two lateral halves united by a symphysis in the mesial line, each branch being articulated with the jugal bone of its corresponding side. Each division is separable by maceration into four or even five pieces: viz. the *dental* (34), which supports the teeth; the *articular* (35), bearing the articulating facet; the *angular* (36), forming the angle of the jaw: and a fourth, placed upon the inner surface of the articular, called the *opercular*, because it corresponds with a bone met with in the lower jaw of reptiles, to which the same name has been applied. The fifth, when present, is very small and unimportant.

(1723.) *Os hyoides and branchiostegous rays.*—The *os hyoides* of a fish is situated as in other vertebrate animals; it is composed of two branches, each made up of several pieces (fig. 313, 37, 38, 39, 40), and is always suspended from the temporal by means of two small ossicles (59), which, as they represent the styloid process of Man, are called the *styloid bones*.

Fig. 313.



Os hyoides and branchial bones of the Perch. (After Cuvier.)

(1724.) Between the two branches of the os hyoides is placed a single central piece (42), which becomes of great importance in Reptiles and Birds; and upon this is the bone which supports the tongue, or the lingual bone (41).

(1725.) The great fissure that exists on each side between the head and shoulder of an osseous fish, wherein the gills are situated, is not closed merely by the opercular bones, but likewise by a broad membranous expansion called the *branchiostegous membrane*, which is adherent to the os hyoides, and assists in forming the great valve of the operculum. This membrane is supported by a series of slender bones derived from the external margin of each branch of the os hyoides, and these are named, from their office, the *branchiostegous rays* (43).

(1726.) *Branchial apparatus.*—Fishes breathe by taking water into their mouths, and forcing it out again through the apertures situated upon each side of the neck; it is thus made to pass between their gills, which form a series of pectiniform vascular fringes supported upon a system of bones called the *branchial arches.* The branchial arches, which are generally four in number on each side, are attached by one extremity to an intermediate chain of bones (53, 54, 55) situated in the mesial line behind the os hyoides, whilst by their opposite extremity they are connected by ligaments to the under surface of the cranium.

(1727.) Every branchial arch consists of several pieces (57, 58, 59, 60, 61), so joined together by ligaments that the whole is perfectly flexible; and their edges are studded with little osseous plates, generally armed with teeth, and so disposed as to prevent food taken into the mouth from being forced out through the branchial fissures with the issuing streams of water; so that, in reality, these pieces fulfil in their way the same office as the epiglottis of Mammalia.

(1728.) *Pharyngeal bones.*—The last parts found to enter into the composition of this portion of a fish's skeleton are called, from their position, the *pharyngeal bones.* They are placed immediately behind the branchial apparatus, and form a second set of masticatory organs, generally even more efficient than the jaws themselves, being for the most part provided with very strong teeth.

(1729.) In the Perch there are eight of these bones, situated just at the entrance to the œsophagus,—two inferior (56), and six above (62): their office and efficiency as organs of mastication must be obvious to the most superficial observer.

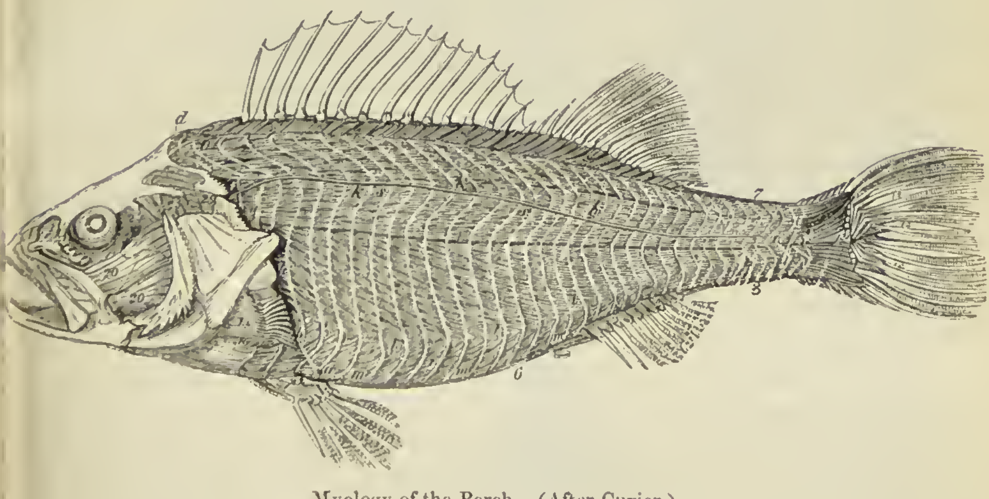
(1730.) Upon reviewing the general disposition of the skeleton in one of the osseous fishes, it is at once apparent that the great instrument of locomotion is the tail, which by extensive and vigorous lateral movements sculls the body rapidly along through the yielding element in which these creatures live. In the construction of the caudal extremity of the skeleton, every precaution has evidently been taken to convert this part of the body into a broad and expanded oar, possessed of the utmost possible flexibility in the lateral direction. No pelvis, therefore, trammels the movements of the spine, neither do any transverse processes limit the extent of flexion from side to side; while, on the contrary, the extraordinary development of the spinous processes, both above and below, and more especially the vertical caudal fin, give an extent of surface proportionate to the wants of the animal.

(1731.) The dorsal and anal fins, situated upon the mesial plane, steady, and perhaps, in some measure, direct the movements of the body; while the arms and legs, or, rather, the pectoral and ventral fins, which are in this case of secondary importance as locomotive instruments, exhibit a very rudimentary condition, and are but feeble agents in progression.

(1732.) The posterior extremities, or ventral fins, are even less efficient than the pectoral in this respect, and their position is found to vary remarkably in different orders. In the Perch, these organs are, as we have seen, attached to the bony framework of the shoulders. In the Carp tribe (Cyprinidæ) they are removed far back towards the commencement of the tail, and the bones supporting them are merely imbedded in the muscles of the abdomen. In the Cod (Gadidæ) the legs are absolutely in front of the arms, being suspended under the throat; and in the Anguilliform fishes, the Eel for instance, the ventral extremities are altogether wanting.

(1733.) Such being the imperfect development of the usual locomotive organs, we are quite prepared to expect a corresponding modification in the disposition and efficiency of different parts of the muscular system. When we compare the muscles of a fish with those of any of the higher Vertebrata, the contrast is indeed very striking.

Fig. 314.



Myology of the Perch. (After Cuvier.)

(1734.) Delicate muscles (fig. 314) are provided for the erection or depression of the different rays sustaining the dorsal and ventral fins, and thus the fins themselves are expanded or folded up at pleasure. Similar fasciculi spread out or approximate the rays of the tail, increasing or contracting at will the extent of surface presented by that organ. The muscles of the pectoral and ventral limbs are small in proportion to the feebleness of these extremities; the muscles of the trunk alone constitute the great bulk of the body, and form the efficient agents in progression.

(1735.) These great lateral masses commence at the back of the head, where they take an extensive attachment to the largely-developed cranium: from this point backwards they fill up the entire space intervening between the skin and the vertebral column, with both of which they are intimately connected, reaching even to the origin of the tail fin. The whole force of these powerful muscles is evidently exerted in bending the spine from side to side, and in effecting those vigorous lateral movements of the tail whereby the fish is propelled through its liquid element. We need, therefore, feel little surprise at the strength with which this part of the body of fishes is not unfrequently endowed, or at the velocity of their movement—at seeing how easily their speed outstrips our fleetest ships—how the Flying-fish (*Exocetus*), urged on by fear, darts like an arrow to a distance through the air—or how the Salmon, in obedience to an imperious instinct, defies even the thundering cataract to stop its course towards the locality where it is instructed by Nature to deposit its eggs.

(1736.) There are sundry tribes of Fishes which, being destined to remain at the bottom of the sea, present certain peculiarities of structure, whereby they are not only distinguished from all others of the class, but form most remarkable exceptions to the general law in accordance with which the Vertebrata are organized.

(1737.) The animals presenting this anomalous configuration are the *Pleuronectidæ*, or Flat-fishes, as they are generally termed, which when at rest lie quietly upon the ground, where, from the colour of the upper part of their bodies, they are scarcely distinguishable. To an ordinary observer the Pleuronectidæ would seem to have their bodies flattened and spread out horizontally, so that, while resting upon their broad and expanded bellies, their eyes, situated upon the back of the head, are thus disposed for the purpose of watching what passes in the water above them; and this, the vulgarly-received opinion, is considerably strengthened by the fact that what is usually called the belly is white and colourless, while the back is darkly coloured and sometimes even richly variegated, so as to harmonize with the prevailing tints of the sea-bottom. Hence the appearance of these fishes is deceptive, and few imagine that, in applying the terms back and belly to the upper and under surfaces of a Plaice or a Turbot, they are adopting a phraseology quite inadmissible in an anatomical point of view.

(1738.) On examining the skeleton of a Flat-fish, we at once see that what we suppose to be the dorsal and ventral regions are in reality the two sides, which are thus strangely different in colour, and that the great peculiarity of their structure is the want of symmetry between the lateral halves of the body, arising from the anomalous circumstance that both the eyes are placed upon the same side of the head. Their cranium, indeed, is composed of the same bones as that of an ordinary fish; but the two lateral halves are not equally developed, and the result is such a distortion of the whole framework of the face, that both the orbits are transferred to the same side of the mesial line of the back.

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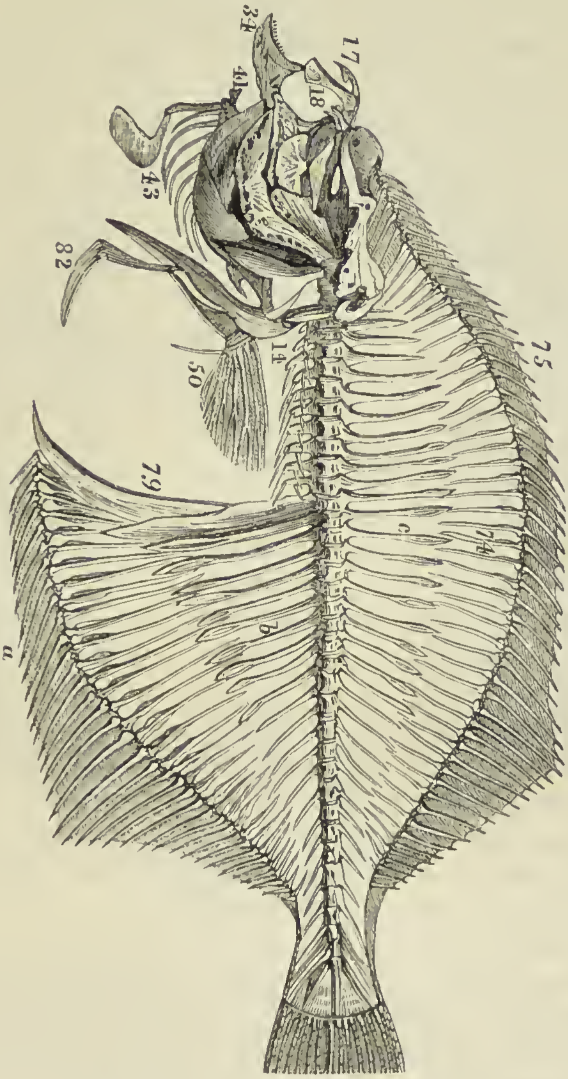
* *πλευρά*, the side; *νηκτής*, a swimmer.

Fig. 315.



Osteology of the Flounder (*Pleuronectes flesus*).

(1739.) The position of the pectoral and ventral fins slightly participates in this want of symmetry; but in other respects the skeleton (fig. 315) precisely corresponds with that of the generality of osseous fishes. The superior and inferior spinous processes of the vertebræ are amazingly developed, and the *interspinous bones* (74) of inordinate length; so that the vertical diameter of the body is disproportionately increased, and the animal is obliged to swim and rest upon one side. The *dorsal fin* (75) runs along the whole length of the back; the *anal fin* (*a*) reaches from the large spines that form the posterior boundary of the abdomen to the *tail*, which latter holds the same position as in other tribes: so that the reader will have little difficulty in comparing the different pieces of the skeleton of the Flounder (*Pleuronectes flesus*) with the corresponding bones of the Perch already described.

(1740.) The skeletons of the cartilaginous fishes (*Chondropterygii*[*]) will require a distinct notice, inasmuch as they present very remarkable peculiarities of no inconsiderable interest. In the Sharks, Skates, and other genera belonging to this important division of the great class we are now considering, the interior of the bones remains permanently cartilaginous; but the skeleton is in some regions incrusted, as it were, with osseous granules. No centres of ossification from which radiating fibres of bony matter progressively extend themselves, as is the case in the osseous fishes, are ever developed; and consequently the skull, although it presents externally the same regions, eminences, and apertures that are usually met with, is never divided into separate bones, but is formed of a single mass of cartilage, in which no sutures or lines of division are ever distinguishable.

(1741.) The face is likewise much more simple in its structure; for, instead of the numerous pieces composing the palato-temporal region of the Perch (§ 1714), two bones only are met with, one of which, the *palatine*, performs the office of an upper jaw and supports the teeth, while the other connects the lower jaw with the cranium. The lower jaw itself, moreover, consists of but one piece on each side, to which the teeth are attached.

(1742.) From the peculiar conformation of the respiratory apparatus, which will be explained hereafter, there is no occasion for any opercular flap; this, therefore, is not present: nevertheless the hyoid and branchial arches resemble pretty much those of osseous fishes; only the latter are situated further backwards, being placed quite behind the skull, under the commencement of the spine.

(1743.) The bones of the shoulder are represented by a strong cartilaginous zone, which in Sharks is quite unconnected with the vertebral column, but in the Skate (*Raia*) it is fixed to two large lateral apophyses derived from the spine (fig. 316). The zone, representing the scapulary apparatus, consists of a single piece, which surrounds the body, and on each side supports the bones of the fore-arm. The enormously-developed pectoral fin is composed of the *carpus*, amazingly augmented in size, and of the no less remarkable hand, which in the Skate is made up of an immense number of fingers or rays, and forms by itself nearly half the circumference of the body.

(1744.) The *pelvis*, or cartilaginous framework that supports the hinder extremities, *i. e.* the ventral fins, is a single transverse piece of cartilage quite detached from the rest of the skeleton: it expands on each side into a broad plate, to which the fin, the representative of the foot of higher animals, is appended; and likewise in the male it gives attachment to additional organs called *claspers,* the use of which will be explained in another place.

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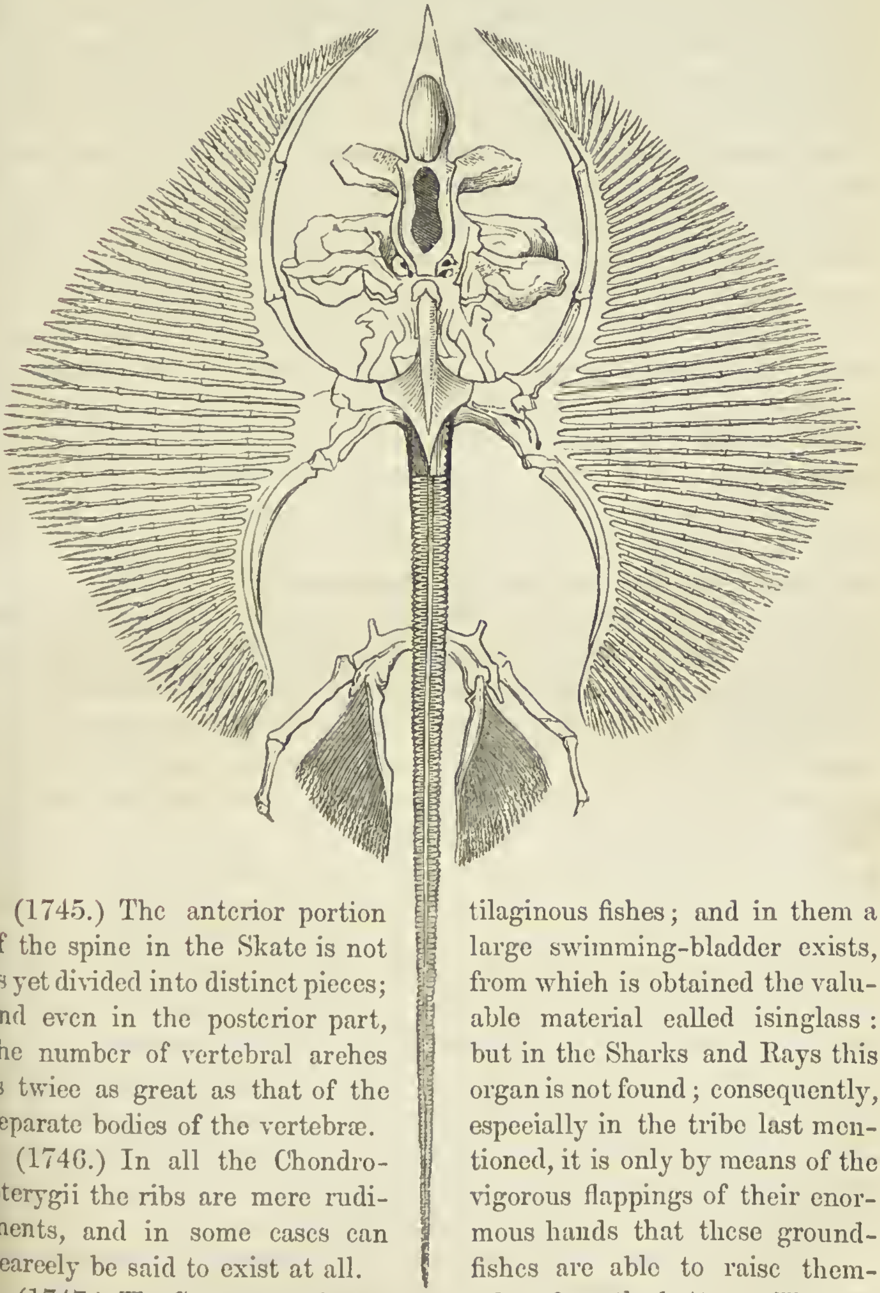
[*] χόνδρος, cartilage; πτερύγιον, a fin.

Fig. 316.

Cartilaginous skeleton of the Skate.



(1745.) The anterior portion of the spine in the Skate is not as yet divided into distinct pieces; and even in the posterior part, the number of vertebral arches is twice as great as that of the separate bodies of the vertebræ.

(1746.) In all the Chondropterygii the ribs are mere rudiments, and in some cases can scarcely be said to exist at all.

(1747.) The Sturgeons (*Sturionidæ*) form a kind of connecting link between the osseous and cartilaginous fishes; and in them a large swimming-bladder exists, from which is obtained the valuable material called isinglass: but in the Sharks and Rays this organ is not found; consequently, especially in the tribe last mentioned, it is only by means of the vigorous flappings of their enormous hands that these ground-fishes are able to raise themselves from the bottom. The disposition and relative importance of different parts of the muscular system is therefore necessarily changed to meet these altered circumstances: the muscles of the trunk, which in osseous fishes formed the great agents in locomotion, become now of secondary importance; while those of the pectoral fins, so feebly developed in the Perch, are massive and powerful in proportion to the unwieldy size of the anterior extremities. Another peculiarity in the skeleton of the Chondropterygii is observable in the construction of the caudal fin, which, even in the Sturgeon and the Shark, notwithstanding the importance which this organ still maintains in those genera as an instrument of locomotion, begins to differ very remarkably from the tail of an osseous fish. It is true that it still exhibits great expansion in a vertical direction, and to a superficial observer, if examined without dissection, might seem to be constructed on the same principles; but, on examining the skeleton of one of these cartilaginous fishes, it will be found that the vertebral column is continued uninterruptedly into the upper half of the generally furcate tail, whilst the lower division of the caudal fin is entirely made up of supplementary rays, appended to the inferior aspect of the caudal vertebræ. Possessing this form of the tail, the transition is by no means abrupt from these highly-organized fishes to the Saurian reptiles, with which, as we shall afterwards see, they exhibit many remarkable affinities.

(1748.) If in the highest Heterogangliata we found that, in addition to the tegumentary skeleton, or shelly covering, so extensively met with among the Mollusca, the first appearances of an internal osseous system became recognizable, we are not on that account to imagine that, as soon as bones become developed internally, the cuticular secretions hitherto denominated *shell* at once disappear, but, on the contrary, must be prepared to expect that, in some form or other, calcareous armour deposited by the skin should still be met with. In Fishes, the coexistence of an internal and of an external skeleton is undeniable; and having already described the former, which has been aptly enough called the *endoskeleton*, it remains for us in the next place to examine the latter or *exoskeleton*, which, as we shall soon perceive, forms no unimportant part of the anatomy of the class under consideration.

(1749.) The most usual form of the cuticular covering of Fishes is that of imbricated scales, with which the whole exterior of the body is compactly encased, as in a suit of armour. Such an investment is admirably adapted to their habits and economy. The dense and corneous texture of the scales, impermeable to water, defends their soft bodies from maceration, while, from their smooth, polished exterior and beautiful arrangement, they ensure the least possible resistance from the surrounding medium as the fish glides along.

(1750.) Examined separately, each scale is found to be partially imbedded in a minute fold of the living and vascular cutis, to which its under surface is adherent. Every scale is, in fact, made up of superimposed laminæ of horny matter secreted by the cutis, precisely in the same way as the shelly covering of a mollusk; and by maceration the different layers may readily be separated,—the smallest and most superficial being of course the first formed, while the largest and most recent are those nearest to the surface of the living skin: as far as relates to the mode of growth, therefore, there is the strictest analogy between the scale of a fish and shell. Various are the forms under which these scales present themselves to the ichthyologist: sometimes, as in the Eel, they are thinly scattered over the surface of a thick and slimy cutis; more generally they form a close and compact imbricated mail; in the Pipe-fishes (*Syngnathidæ*) the whole body is covered with a strong armour composed of broad and thick calcareous plates; and in the Coffin-fishes (*Ostracionidæ*) the integument is converted into a strong box made up of polygonal pieces anchylosed together, so that the tail and fins alone remain moveable.

(1751.) The Sturgeon is covered with broad shield-like plates. The skin of the Shark is densely studded with minute sharp spines of almost crystalline hardness; and in many Skates, as in the Thornback, similar cuticular appendages, but of more considerable dimensions, are distributed over the back and tail, forming very efficient defensive weapons.

(1752.) But cutaneous spines, although while in a rudimentary condition they are obviously mere extraordinary developments of scales, may occasionally become of sufficient size and importance to make them convertible to various unexpected uses; and when thus exaggerated in their dimensions and appropriated to distinct offices, they assume so much of the character of true bone, that it is no longer easy to demonstrate their real nature, more especially as they then become in many cases really articulated by means of very perfect joints with different pieces of the *endoskeleton* properly so called.

(1753.) Let us examine this important subject with a little attention, and we shall soon perceive how closely the *endoskeleton* and the *exoskeleton* may become connected, not to say interchangeable, with each other. There is no possibility of mistaking the spines and tubercles upon the back of a common Skate for anything but cuticular appendages, secreted in the same manner as scales from the surface of a vascular pulp; but in the Fireflare (*Trygon pastinaca*), where, instead of the scattered hooks of the former species, we find a single sharp and serrated spine projecting like a bayonet from the upper surface of the root of the tail, the analogy between this formidable and bone-like organ and an epidermic structure becomes apparently more remote, and, did we not know that the fish possessing such a weapon had no ossified bones internally, we might be tempted to regard this appendage as a process derived from the *endoskeleton*.

(1754.) The spines of the common Stickleback (*Gasterosteus*) are indubitable derivations from the cuticle; but they are fastened by moveable articulations to the sides of the body, and are raised or depressed by means of muscles inserted into their bases. Advancing one step further, we find in *Silurus* the first ray of the pectoral fins enormously developed and forming a strong serrated weapon of a very formidable description, which although both in shape and structure exactly comparable to the spine upon the tail of the Fireflare, is nevertheless connected by a most beautiful and perfect joint with the bones of the shoulder, so that it might easily be regarded as forming part of the *endoskeleton*, did not its peculiar structure indicate its real nature.

(1755.) We thus arrive at the important conclusion that different portions of the *exoskeleton* become approximated in character to those of the *endoskeleton*, or, in truth, really convertible into true bone; and with this fact before us it becomes easy to understand the nature of various parts of the skeleton of a fish, which, upon any other supposition, would be not a little puzzling to the comparative osteologist.

(1756.) The nature of the rays of the dorsal and anal fin of the Perch, for example, together with the *interspinous* bones upon which they are sustained, is quite unintelligible if they are regarded as belonging to the *endoskeleton*; and no dismemberments of the osseous system as yet imagined, or supposed subdivisions of the vertebræ into a greater number of elemental pieces than we have enumerated, has been able to solve the difficulty; but if they are regarded as ossified derivations from the *exoskeleton*, all difficulties at once vanish.

(1757.) Again, the *opercular bones* (fig. 312, 28, 30, 32, 33) forming the gill-covers of an osseous fish have been a fruitful source of discussion; and M. Geoffroy St.-Hilaire* was reduced to the necessity of recognizing in these broad plates the ossicles of the human ear, which, after dwindling to a rudiment in the descending scale of vertebrate animals, suddenly reappeared in a new and exaggerated form. "J'ai peu vu dans la série des êtres de ces résurrections d'organes se remontrant subitement dans une classe après avoir disparu dans une ou deux de celles qui la précède dans l'échelle," are the impressive words of Cuvier upon a similar occasion; and it is certainly far more simple to imagine the epidermic plates of the Sturgeon ossified and converted into bone, than to be compelled to have recourse to the bold speculations of the French anatomist regarding the real nature of these opercular portions of a fish's skeleton†.

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[*] Philosophie Anatomique des Pièces osseuses des Organes respiratoires. 8vo. Paris, 1818.

[†] The different opinions on the nature or homology of the opercular bones may be reduced to two principles: first, that they are modifications of parts of the ordinary skeleton; secondly, that they are superadded bones peculiar to Fishes: the latter view is that taken by Cuvier. According to the former, which is the more philosophical mode of considering them, three opinions have been offered. The first by Spix and Geoffroy, that they are gigantic representatives of the ossicles of the ear, otherwise absent in the skeleton of Fishes: this view has been adopted by Professor Grant.

(1758.) In connexion with the locomotive organs we must here notice one of the most elegant contrivances met with in the whole range of animated nature, by which the generality of fishes are enabled to ascend towards the surface, or to sink to any required depth, without exertion.

(1759.) The apparatus given for this purpose is called the *swimming-bladder*, and consists of a reservoir of air (fig. 317, *p*) placed beneath the spine, in which position it is firmly bound down by the peritoneum. The outer coat of this bladder is very strong, and composed of a peculiar fibrous substance from which isinglass is obtained, but it is lined internally with a thin and delicate membrane. The shape of the *swimming-bladder* varies considerably in different tribes. In the Perch it is a simple cylinder closed at both extremities; sometimes it gives off branched appendages; sometimes, as in the Cyprinidæ, it is divided into two portions, one anterior and the other posterior, by a deep central constriction; but, whatever its shape, its office is the same, namely, to alter the specific gravity of the fish, and thus to cause it to rise or sink in the medium it inhabits. By simply compressing this bladder by approximating the walls of the abdomen, or occasionally by means of a muscular apparatus provided for the purpose, upon a principle with which every one is familiar, the fish sinks in proportion to the degree of pressure to which the contained air is subjected; and as the compressed air is again permitted to expand, the creature becoming more buoyant rises towards the surface.

(1760.) In the Perch, and many other fishes, this organ is entirely closed, so that there is no escape for the contained air; and in such it has been found that if they are suddenly brought up by means of a line from any great depth, the gas, being no longer compressed by the weight of the column of water above, and having no exit, bursts the swimming-bladder, and sometimes distends the abdomen to such an extent, that it pushes the stomach and œsophagus into the fish's mouth.

(1761.) In other cases, however, a provision is made apparently with the view of obviating such an accident, and a kind of safety-valve provided through which the air may be permitted to escape: thus, in the Carp, a tube communicates between the interior of the air-bladder and the œsophagus, and in the Herring a similar communication is met with between this organ and the stomach.

(1762.) The gas which fills the *air-bladder* has been found in many

Secondly, that they are dismemberments of the lower jaw, which by the detachment of the opercular bones from the ramus is rendered more simple in its composition than in Reptiles,—a view proposed by M. de Blainville and temporarily adopted by Bojanus and Oken, but refuted by the complicated structure of the lower jaw in certain sauroid fishes, as the *Lepidosteus*, which likewise possesses the opercular bones. Thirdly, that they are parts of the dermal skeleton—in short, scales modified in subserviency to the breathing function,—an opinion first proposed by Professor Owen, in his Lectures on Comparative Anatomy at St. Bartholomew's Hospital in 1835, and which is the view here adopted.

cases to be nearly pure nitrogen; but in fishes that live at a great depth, Messrs. Configliacchi* and Biot ascertained that oxygen was substituted, whence it has been presumed that this apparatus was in some way or other an auxiliary in respiration; and some authors have even gone so far as to see in the swimming-bladder the representative of the lungs of aërial Vertebrata. But, however this may be, the gas enclosed is indubitably a product of secretion, being derived either from the lining membrane of the viscus, or from a glandular structure which may frequently be distinctly pointed out in its interior.

(1763.) Cuvier justly observes that, whatever opinions may be entertained relative to the use of the air-bladder, it is difficult to explain how so considerable an organ has been refused to so many fishes—not only to those which ordinarily remain quiet at the bottom of the water, as Skates and Flat-fishes, but to many others that apparently yield to none either in the rapidity or facility of their movements, such as the Mackerel for instance; yet even while the common Mackerel (*Scomber scomber*) has no air-bladder, a very nearly allied species (*Scomber pneumatophorus*) is provided with one; and of this many other instances might be adduced.

(1764.) From the circumstances under which fishes seize and swallow their prey, it must be evident that they are incapable of enjoying any very refined sense of taste. Those species which are carnivorous are of necessity compelled to catch with their teeth, and thus retain a firm hold of the active and slippery food they are destined to devour. To divide or masticate their aliment would be impracticable; and even were they permitted so to do, the water which perpetually washes through the interior of their mouths would obviously preclude the possibility of appreciating savours. In the construction of the mouth of a fish we therefore find, generally speaking, that every part has been made subservient to prehension: teeth, sometimes in the form of delicate spines, or else presenting the appearance of sharp recurved hooks, have been fixed in every possible situation where they could be made available as prehensile organs: not only are the jaws densely studded with these penetrating points, but they are occasionally placed on every bone which surrounds the oral cavity or supports the entrance of the pharynx. The intermaxillary, the maxillary, and the palatine bones, the vomer, the branchial arches, the pharyngeal bones, and even the tongue itself, may all support a dental apparatus, either of the same description or composed of teeth of different shapes; generally, however, some of these bones are unarmed, and occasionally teeth of any kind are altogether wanting.

(1765.) But if such is the most usual arrangement of the dental apparatus in fishes, we must be prepared to find, in a class so extensive as that we are now investigating, various modifications both in the form and arrangement of the teeth, adapting them to the diverse habits and necessities of individual species; and a few of these we must not omit to notice in this place.

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* "Sull' analisi dell' aria contenuta nella vescica natatoria dei Pesci." Pavia, 1809, 4to.

(1766.) The *Myxine*, or Hag-fish, one of the lowest of the entire class, possesses no osseous framework to which teeth could be attached; and yet, from the parasitical life which this creature leads, it has need of dental organs of considerable efficiency. The Myxine, feeble and helpless as the casual observer might suppose it, is in reality one of the most formidable assailants with which the larger fishes have to contend, since neither strength nor activity avail aught in defending them against a foe apparently so despicable. Fixing its mouth firmly to the skin of its comparatively gigantic victim, the Myxine bores its way into its flesh by means of a dental apparatus of a very extraordinary description. A single fang-like tooth is fixed to the median line of the palate, and the tongue is armed on each side with two horny plates deeply serrated: thus provided, the Myxine, when it attacks its prey, plunges its palatine hook into its flesh; and thus securing a firm hold, the lingual saws, aided by the suctorial action of the mouth, tear their way to its very vitals*.

(1767.) In the Lamprey the whole interior of the mouth is studded with horny teeth, not merely fixed to the palate and tongue, but to the cartilaginous representative of the inferior maxilla and to the inner surface of the lips.

(1768.) In the Carp tribe (*Cyprinidæ*) the jaws are destitute of teeth; but in the throat there is a singular apparatus serving for the mastication of their food. The basilar bone at the base of the skull supports a broad three-sided dental plate, which might be compared to an anvil; while the two inferior pharyngeal bones are each armed with four or five large teeth, so disposed that, by working upon the piece first mentioned, they bruise and triturate the aliment before it is permitted to pass into the digestive cavity.

(1769.) In Skates (*Raidæ*) the internal surface both of the upper and lower jaws is so covered with teeth, that they have the appearance of a tessellated pavement: these teeth are sometimes flat and smooth, so as to be merely useful in crushing prey; but in many species they are prolonged into sharp hooks adapted to prehension.

(1770.) In Sharks a beautiful provision is met with. Several rows of teeth placed one behind the other are found laid flat, and concealed behind the jaw. One row only, composed of triangular cutting teeth, stands erect and ready for use; but when these fall off, blunted and unfit for service, the next row rises to take their place; and thus a succession of efficient weapons are given to these terrific monsters of the ocean.

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* Professor Owen, 'Odontography; or a Treatise on the Comparative Anatomy of the Teeth, their Physiological Relations, Mode of Development, and Microscopic Structure,' &c. 4to. Baillière, 1840.

(1771.) We will not enlarge further upon this portion of our subject; enough has been said for our present purpose, and the reader will find elsewhere abundant information*.

(1772.) The teeth of osseous fishes are generally firmly anchylosed to the bones that support them, although in a few instances they are found fixed in sockets, as in the rostral teeth of the Saw-fish (*Pristis*), and in the mouth of *Sphyræna, Acanthurus, Dictyodus,* &c.† But there are other modes of attachment only met with among fishes, some of which are not a little curious; and Professor Owen, in his truly splendid work above referred to, thus describes the most important:—

"In the Cod-fish, Wolf-fish, and some other species, in proportion as the ossification of the tooth advances towards its base and along the connecting ligamentous substance, the subjacent portion of the jaw-bone receives a stimulus, and developes a process corresponding in size and form with the solidified base of the tooth. In this case the inequalities of the opposed surfaces of the tooth and maxillary dental process fit into each other, and for some time they are firmly attached together by a thin layer of ligamentous substance; but in general anchylosis takes place to a greater or less extent before the tooth is shed. The small anterior teeth of the Angler (*Lophius*) are thus attached to the jaw; but the large posterior ones remain always moveably connected by highly elastic, glistening ligaments, which pass from the inner side of the base of the tooth to the jaw-bone. These ligaments do not permit the tooth to be bent outwards beyond the vertical position when the hollow base of the tooth rests upon a circular ridge growing from the alveolar margin of the jaw; but the ligaments yield to pressure upon the tooth in the contrary direction, and its point may thus be directed towards the back of the mouth; the instant, however, that the pressure is remitted, the tooth flies back, as by the action of a spring, into its usual erect position. The deglutition of the prey of this voracious fish is thus facilitated and its escape prevented.

"The broad and generally bifurcate osseous base of the teeth of Sharks is attached by ligaments to the ossified or semiossified crust of the cartilaginous jaws. The teeth of the *Salarias* and certain Mugiloids are simply attached to the gum. The small and closely-crowded teeth of the Rays are also connected by ligaments to the subjacent maxillary membrane. The broad tessellated teeth of the Eagle-Rays have their attached surface longitudinally grooved to afford them better holdfast; and the sides of the contiguous teeth are articulated together by true serrated or finely-undulating sutures, which mode of fixation of the dental apparatus is unique in the animal kingdom.

"If the engineer would study the model of a dome of unusual strength, and so supported as to relieve from its pressure the floor of a vaulted chamber beneath, let him make a longitudinal section of one of the pharyngeal teeth of a Wrasse (*Labrus*). The base of this tooth is slightly contracted, and is implanted in a shallow circular cavity, the rounded margin of which is adapted to a circular groove in the contracted part of the base; the margin of the tooth, which immediately transmits the pressure to the bone, is strengthened by an inwardly projecting convex ridge. The masonry of this internal buttress and of the dome itself is composed of hollow columns, every one of which is placed so as to transmit in the due direction the superincumbent pressure.

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* *Vide* Yarrell's British Fishes. 8vo. 2 vols.

† Owen, Odontography, p. 6.

"In another case, in which long and powerful piercing and lacerating teeth were evidently destined, from the strength of the jaws, to master the death-struggles of a resisting prey, we find the broad base of the tooth divided into a number of long and slender processes, which are implanted like piles in the coarse osseous substance of the jaw; they diverge as they descend, and their extremities bend and subdivide like the roots of a tree, and are ultimately lost in the bony tissue. This mode of implantation, which I have detected in a large extinct Sauroid fish (*Rhizodus*), is perhaps the most complicated which has yet been observed in the animal kingdom."

(1773.) For a full account of the growth and development of the teeth of Fishes, we must refer the reader to the same source from which we have extracted the preceding paragraphs; nevertheless the following is a brief abstract of Professor Owen's views upon this subject.

(1774.) In all fishes, the first step in the formation of a tooth is the production of a simple papilla from the surface either of the soft external integument, as in the formation of the rostral teeth of the Saw-fish (*Pristis*), or of the mucous membrane of the mouth, as in the rest of the class. In these primitive papillæ there can be very early distinguished a cavity containing fluid, and a dense membrane (*membrana propria*) surrounding the cavity (and itself covered by the thin buccal mucous membrane), which gradually becomes more and more attenuated as the papilla increases in size. The pulp-substance, or contents of the *membrana propria*, remains for some period in a fluid or semifluid condition; granules are ultimately developed in it, which at first float loosely, or in small aggregated groups, in the sanguineo-serous contents of the pulp. These granules soon attach themselves to the inner surface of the *membrana propria*, if they be not originally developed from that surface. The whole of the contents of the growing pulp becomes soon after condensed by the numerous additional granules which are rapidly developed in it after it has become permeated by the capillary vessels and nerves. The particles become arranged into linear series or fibres—an appearance which is first apparent at the superficies of the pulp, to which the fibres are vertical. At this period ossification commences in the dense and smooth *membrana propria* of the pulp, and is thence continued centripetally in the course of the above-mentioned lines towards the base of the pulp. Lastly, around the capillaries of the pulp the granules become condensed into concentric layers, which then form the walls of minute tubes, visible on a microscopic examination of the substance of the tooth.

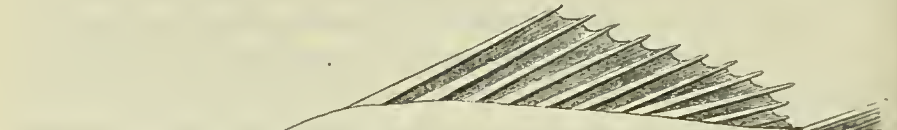
(1775.) In some genera, as *Balistes* and *Chrysophrys*, an enamel-pulp is developed from the inner surface of the capsule which surrounds the bone-pulp, and by this organ the surface of the teeth of such fishes is coated with enamel in a manner to be described more at large hereafter.

(1776.) In most osseous fishes, in addition to the lips (which, even when fleshy, being destitute of proper muscles, would be unable to retain food in the mouth), there is generally, behind the front teeth in each jaw, a valve formed by a fold of the lining membrane of the mouth, and directed backwards, so as efficiently to prevent the aliment, and more especially the water swallowed for the purpose of respiration, escaping again from the oral orifice*.

(1777.) Fishes have no salivary glands, as saliva to them would be entirely useless: their œsophagus (fig. 317, *g*; fig. 327, *d*) is capacious and, from the circumstance of their having neither neck nor thorax, extremely short; so that the food when seized is conveyed at once into the stomach.

(1778.) The stomach itself is generally a wide cul-de-sac (fig. 317, *h*), the shape and proportionate size of which vary of course in different species. Its walls are most frequently thin, and the lining membrane gathered into large longitudinal folds (fig. 327, *c*), so as to admit of con-

Fig. 317.



Plan of the general arrangement of the viscera in a Fish.

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* Cuvier et Valenciennes, Histoire Naturelle des Poissons, p. 367.

siderable distention; but occasionally, as for example in the Mullets, its muscular walls are so thick that it might almost deserve the name of gizzard, and in such fishes its power of crushing the food is no doubt considerable.

(1779.) The intestinal canal in the osseous fishes is a simple tube (fig. 317, *i*), folded in sundry gyrations proportioned to its length; but in the cartilaginous families, such as the Sharks, the Rays, and the Sturgeons, it presents internally a very remarkable arrangement, evidently intended to increase the extent of surface over which the digested aliment may be spread, for the purpose of absorbing its nutritive portions. In these tribes a spiral valve (fig. 327, *h*) winds in close turns from the pyloric to the anal extremity of the capacious intestine; so that, although externally the intestine appears short in proportion to the size of the animal, its mucous lining is exceedingly extensive.

(1780.) In addition to the biliary secretion which we have met with in the lower animals, another system of chylopoietic glands for the first time makes its appearance in the class before us, from which a fluid termed the *pancreatic* is poured into the intestine. In the osseous fishes this viscus presents the simplest condition of a gland, consisting of simple cæca (fig. 317, *n n*); sometimes, as in the Perch, only three in number; at others, as for instance in the Salmonidæ, extremely numerous. From these appendages a glairy fluid, resembling saliva in composition, is abundantly secreted, and becomes mixed with the bile immediately upon its entrance into the intestine.

(1781.) In the cartilaginous fishes, such as Sharks and Rays, the pancreas exhibits a more perfect development, and already presents the appearance of a conglomerate gland (fig. 327, *f*), from which the pancreatic fluid is conveyed into the intestine through a common duct.

(1782.) The liver of fishes is proportionately very large, and generally contains abundance of oil. The bile derived from it is received into a gall-bladder (fig. 317, *c*), from which a duct of variable length in different species conveys it into the intestine, in the immediate vicinity of the pylorus.

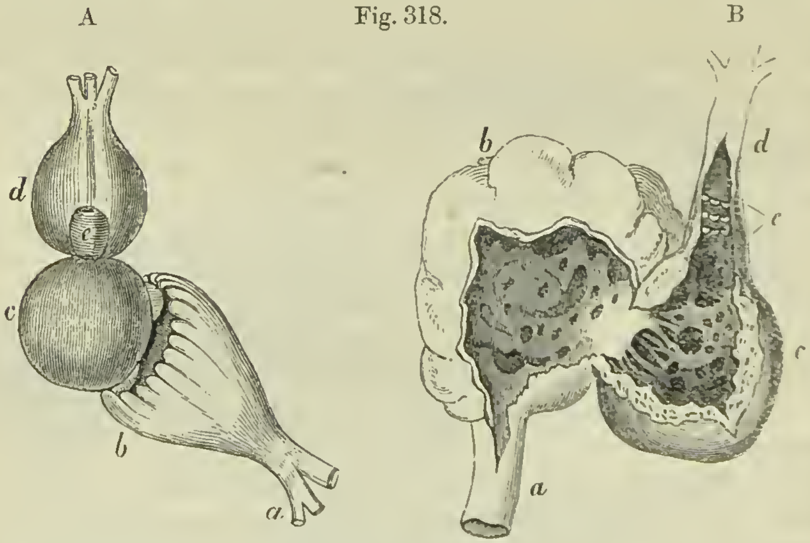
(1783.) It is in these animals that we for the first time find the biliary secretion separated from venous blood; and consequently they are provided with a new arrangement of the blood-vessels of the abdomen, which they possess in common with the other Vertebrata, forming what is termed by anatomists *the system of the vena portæ*. The veins derived from the *stomach*, the *intestines*, and the *spleen*, which last viscus now makes its appearance, instead of conveying their contents to the heart, plunge into the substance of the liver and there again subdivide into capillary tubes, thus furnishing to the liver abundance of venous blood, from which the hepatic secretion is elaborated.

(1784.) The *spleen*, now for the first time met with in the animal creation, is a highly vascular organ, generally enclosed in the mesentery between two folds of the intestine (fig. 317, *m*), and evidently, in position, presenting no precise relations with the stomach. It receives a large supply of arterial blood, which becomes converted into venous as it circulates through this organ, and in that state is transmitted to the liver through the *portal* system of veins.

(1785.) Another important addition to the animal economy, peculiar to the Vertebrate division of animals, is the *lymphatic or absorben system of vessels*, which in Fishes are abundantly distributed through the body, and ramify like a rich network over the walls of the intestine. These pour the materials absorbed from the body, and the products of digestion, into the principal venous trunks, to be mixed up with the circulating blood *.

(1786.) The circulation of the blood in Fishes is carried on by the assistance of a heart composed of two cavities only, which receives the vitiated blood after it has circulated through the system, and propels it through the branchiæ, where it is exposed to the influence of the oxygen contained in the surrounding medium. After being thus purified, the blood is collected from the respiratory organs by the radicles of the branchial veins ; and these latter vessels, by their union, form the aorta.

Fig. 318.



A. Heart of *Lophius piscatorius*. B. Ordinary structure of a Fish's heart. In both drawings, *a*, represents the vena cava; *b*, the auricle; *c*, the ventricle; *d*, the bulbus arteriosus; and *e*, the valvular apparatus guarding its commencement.

There is, therefore, no systemic heart in Fishes, the aorta itself serving to propel the slow-moving blood in its course through the arterial system.

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* For a detailed account of the lymphatic system of Fishes, the reader is referred to the following authors :—Monro, 'Anat. and Physiol. of Fishes,' fol.: Hewson, Phil. Trans. 1769 ; Fohmann, 'Histoire générale des Lymphatiques des Vertèbres,' Heidelberg and Leipzig, fol. 1827.

(1787.) The heart (fig. 317, *o*) is enclosed in a pericardium, and situated beneath the pharyngeal bones and branchial apparatus, the cavity in which it is lodged being separated from the peritoneum by a kind of tendinous diaphragm, and also by a capacious sinus, in which the venous blood derived from all parts of the body is collected preparatory to its admission into the heart.

(1788.) The auricle of the heart (fig. 318, B, *b*) is contained within the pericardium: it varies greatly in form in different fishes, but its capacity is generally considerably greater than that of the ventricle; and its walls are thin, but, nevertheless, present distinct fleshy columns.

(1789.) The blood derived from the great sinus before mentioned enters the posterior part of the auricle of the heart by a large orifice, which is guarded by two membranous valves so disposed as to prevent the reflux of the blood during the contraction of the auricular chamber. The ventricle is strong and fleshy; and at its communication with the auricle there is a strong mitral valve. The commencement of the branchial artery (fig. 318, A, *d*) is so muscular and capacious, that it might almost be considered as forming a second ventricular chamber: this portion, which has been distinguished by the name of the *bulb* (*bulbus arteriosus*), is separated from the ventricle by strong valves; and in the cartilaginous fishes, as, for instance, in the Shark, there are several rows of semilunar valves (fig. 318, B, *e*), so disposed as most efficiently to prevent the blood from being driven back again into the ventricle. In the heart of *Lophius* (fig. 318, A), the conformation of the cavities is very peculiar: the auricle (*b*) is large and pyriform, and the ventricle (*c*) of a globular shape. But the most singular feature in its structure is the valve between the ventricle and the bulb (*d*): this is a soft fleshy protuberance (*e*), perforated in the centre, which projects into the cavity of the bulb, and allows the blood to pass freely in one direction; but the sides of the canal collapse, and close the orifice, if the blood is forced back from the bulb towards the ventricle.

(1790.) Issuing from the pericardium, the branchial artery runs beneath the centre of the branchial apparatus, dividing into as many trunks as there are branchial arches, to each of which a vessel is given off.

(1791.) To each branchial arch are attached a great number of vascular lamellæ placed parallel to each other, like the teeth of a comb. The branchial artery, which runs in a groove situated upon the convexity of the corresponding arch, sends off a twig to every one of these laminæ; and this vessel, after twice bifurcating, divides into an infinite number of little ramusculcs, which run across both surfaces of the branchial fringe, and terminate by becoming converted into capillary veins.

(1792.) The radicles of the branchial veins all open into a venous canal which runs along the internal margin of each lamella, and these last terminate in the great vein of the corresponding branchial arch, which runs in the same groove as the artery, but is more deeply situated, and moreover runs in the opposite direction: that is to say, the branchial artery, derived from the heart, and coming from the ventral aspect of the body, diminishes in size as it mounts towards the back, and gives off twigs to the branchial fringe; whereas the branchial vein, on the contrary, receiving blood from the lamellæ of the branchia, increases in diameter as it approaches the dorsal region.

(1793.) On leaving the gills, the branchial veins assume the appearance and perform the function of arteries. The anterior, even before escaping from the branchial arch, gives off ramifications to different parts of the head; and the heart and parts adjacent likewise receive their supply of arterial blood from a branchial vein.

(1794.) The veins derived from all the branchial arches ultimately unite and form the *aorta*, which evidently corresponds to the aorta of Mammalia, although it has neither auricle nor ventricle at its commencement.

(1795.) The aorta, while in the abdomen, runs beneath the spine, and gives arteries to the viscera in the usual manner; but at the commencement of the tail it becomes enclosed in the inferior vertebral arches, by which it is defended to its termination.

(1796.) There is yet another set of organs, which, as we ascend from inferior to higher forms of animal life, we encounter for the first time in the class before us—an apparatus for elaborating the urinary secretion, which is peculiar to the Vertebrate classes.

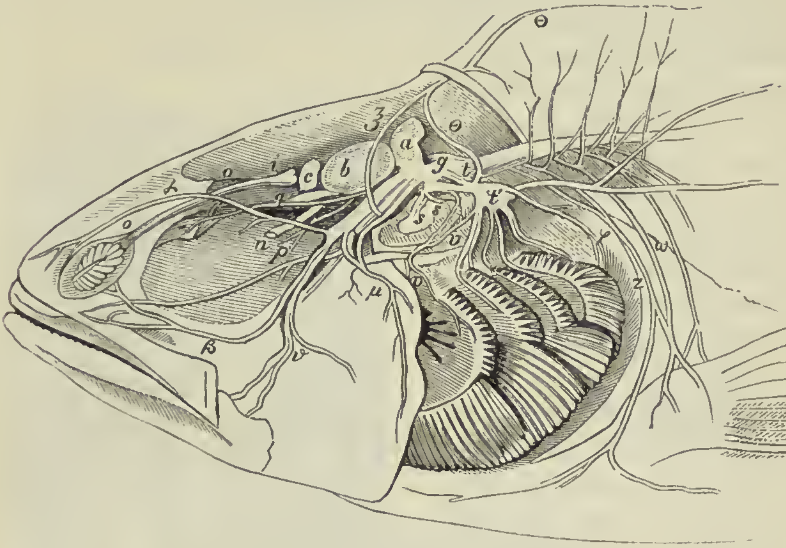
(1797.) The kidneys in Fishes are very voluminous: they are situated on each side of the mesial line, immediately beneath the bodies of the vertebræ, and extend along the whole length of the abdomen, not unfrequently reaching to the base of the skull, where their anterior portion (fig. 317, *e*) lies above the branchial apparatus. The ureters (fig. 317, *f*) generally terminate in a kind of bladder-like dilatation, the orifice of which is found behind that of the vulva (*s*).

(1798.) Examined minutely, the substance of the kidney is found to be entirely composed of microscopic tubules, which terminate in the ureters: these uriniferous tubes are variously contorted, but of equable diameter throughout; and they end, towards the periphery of the kidney, in blind extremities.

(1799.) The skin of these aquatic animals is perpetually lubricated by an abundant mucous secretion furnished by muciparous follicles, or secreted in long tubular organs placed beneath the skin. In the Skate the vessels last mentioned are remarkably large, and their distribution very extensive.

(1800.) The brain of an adult fish occupies but a small portion of the cranial cavity,—the space between the *pia mater*, which invests the brain, and the *dura mater*, which lines the skull, being occupied by a loose cellular tissue filled with fluid: there is consequently no serous or *arachnoid* cavity, such as exists in Man. It has been remarked that the interval between the cranium and the brain is considerably less in young than in mature fishes—a fact which sufficiently proves that in them the brain does not grow in the same proportion as the rest of the body; and, indeed, the size of the brain is nearly equal in individuals of the same species, even although the body of one be twice as large as that of the other*.

Fig. 319.



Brain and cerebral nerves of the Perch (after Cuvier): *a*, the cerebellum; *b*, cerebrum; *c*, olfactory ganglia; *i*, bulbous commencement of the olfactory nerve; *o o*, olfactory nerve, terminating in the nasal capsule; *n*, optic nerve; *p*, *q*, third, fourth, and sixth pairs of nerves, appropriated, as in Man, to the muscles of the eyeball; *α*, ophthalmic branch of the fifth pair; *β*, superior maxillary branch of ditto; *θ*, inferior maxillary branch of ditto; *μ*, opercular branch; *ξ*, branch of the fifth pair, mounting upwards to join Θ, a branch from the eighth pair, running to supply the dorsal region of the body; *s s*, auditory nerve; *t t'*, nerves belonging to the eighth pair; *w*, *z*, nerves answering to the spinal recurrent.

(1801.) In these, the lowest forms of Vertebrata, the brain consists of several masses placed one behind the other, either in pairs or singly; these masses, in fact, may be regarded as so many distinct ganglia, the complexity and perfection of which we must expect to become gradually increased as we proceed upwards towards mammiferous quadrupeds.

(1802.) The anterior pair of ganglia (figs. 319, *c*; 320; 322, *a*) invariably give origin to the olfactory nerves, and consequently may be justly looked upon as presiding over the sense of smell. These ganglia are, in fact, the representatives of those masses which in Man are erroneously called the "olfactory nerves;" for even in the human subject, although their real nature is obscured by the enormous development of other parts of the encephalon, the so-called nerves are not nerves at all, but really lobes of the brain from which the true nerves emanate.

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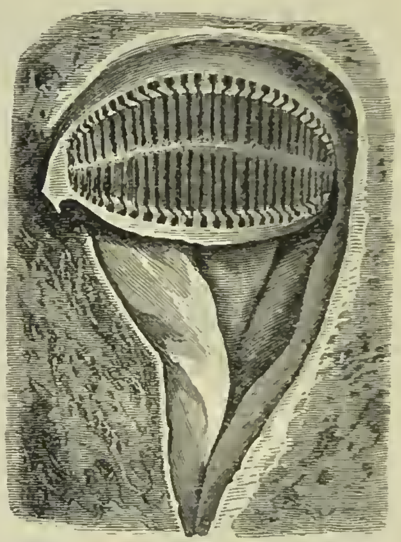
* Cuv. et Val. *op. cit.*

(1803.) The olfactory nerves of Fishes, derived from the lobes alluded to, vary greatly in composition and proportionate size: sometimes they are quite capillary; sometimes thick, though still simple; occasionally they are double or triple, and in some cases are composed of numerous fibres bound up in fasciculi.

Fig. 320.



Organ of smell in the Skate.

(1804.) The organs of smell to which these nerves are destined are of very simple structure:—Two excavations are found near the anterior part of the snout, lined with a delicate pituitary membrane, which is variously folded, in order to increase the extent of the sentient surface (fig. 320); and it may be presumed that, from the number of plicæ, which varies amazingly, some estimate may be formed of the relative perfection of the sense of smell in different genera. Into each olfactory chamber the water is freely admitted by two distinct orifices, while behind the pituitary membrane the olfactory nerve swells out into a ganglion (fig. 322, 1), from which nervous fibrils radiate, to be distributed over the plicated lining of the nose (*k*).

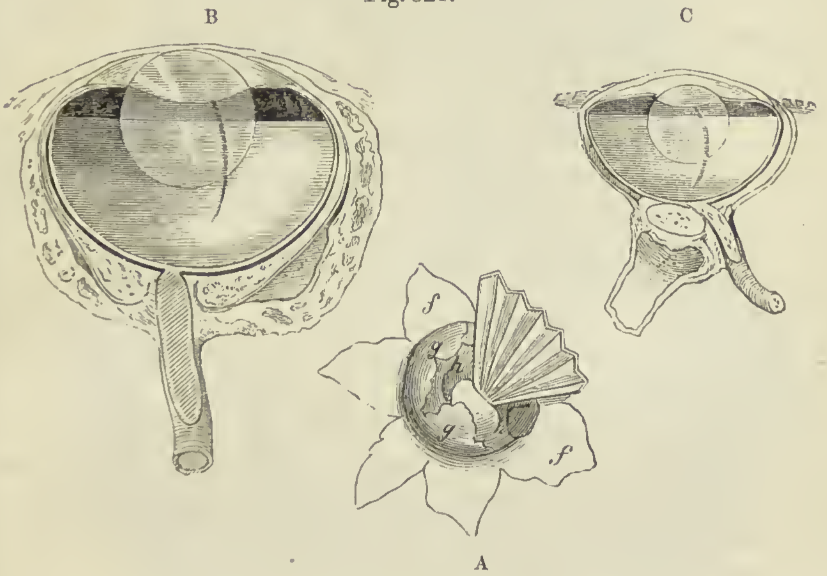
(1805.) The second pair of ganglia met with in the brain of a Fish (fig. 322, *b*) give origin to the optic nerves (2), and may therefore very properly be regarded as representing the *tubercula quadrigemina* of the mammiferous brain. The nerves of vision derived therefrom have no commissure, and present in many species a peculiar structure which is not a little remarkable, each nerve being composed of a broad band of nervous substance, folded up like a fan, and enclosed in a dense membrane, so that when unfolded it presents the appearance delineated at fig. 321, A.

(1806.) The eye itself differs in many points of structure from that of terrestrial Vertebrata, its organization being of course adapted to bring the rays of light to a focus upon the retina in the denser element in which the fish resides; the power of the crystalline lens is therefore increased to the utmost extent, and the antero-posterior diameter of the eyeball necessarily contracted in the same ratio, in order that the retina may be placed exactly in the extremely short focus of the powerful lens.

(1807.) The eyes of all the Vertebrata are constructed upon principles essentially similar, and present the same tunics and lenses as are met with in the human eye, and, generally speaking, arranged in the same manner as in Man. It is not our intention, therefore, in the following pages minutely to describe the anatomy of the eye in every class which will come under our notice ; but taking the human eye, with the construction of which we presume our readers to be intimately acquainted, as a standard of comparison, point out those modifications of the general type of structure common to this division of animated nature.

(1808.) The first thing which strikes the attention of the anatomist, when examining the eye of a fish, is the size of the crystalline lens, and its spherical form. This shape, and the extreme density of texture which the lens exhibits, are, indeed, perfectly indispensable. The aqueous humour, being nearly of the same density as the external element, would have no power in deflecting the rays of light towards a focus, and consequently the aqueous fluid in fishes is barely sufficient in quantity to allow the free suspension of the iris : the vitreous humour, from the same reason, would be scarcely more efficient than the aqueous in changing the course of rays entering the eye, and hence the necessity for that extraordinary magnifying power conferred upon the lens.

Fig. 321.



Structure of the eye in Fishes.

(1809.) But the focus of the crystalline will be short in proportion as its power is increased : every arrangement has therefore been made to approximate the retina to the posterior surface of the lens ; the eyeball is flattened, by diminishing the relative quantity of the vitreous humour ; and a section of the eye (fig. 321, B, C) shows that its shape is very far from that of a perfect sphere. This flattened form could not, however, have been maintained in fishes, had not special provision been made for the purpose in the construction of the sclerotic : the outer tunic of the eye, therefore, generally contains two cartilaginous plates imbedded in its tissue, which are sufficiently firm in their texture to prevent any alteration in the shape of the eyeball; and in some of the large fishes the sclerotic is actually converted into a cup of bone presenting orifices at the opposed extremities—one for the insertion of the transparent cornea, the other for the admission of the optic nerve.

(1810.) The vitreous humour and crystalline lens in many fishes are kept *in situ* by a ligament placed for the purpose. This is a delicate falciform membrane derived from the retina (fig. 321, B, C), which plunges into the vitreous humour, and, being continued along the internal concavity of the eye, is fixed to the capsule of the lens. In some fishes, as the Salmon, this ligament is of a dark colour; and in the Conger there are two such bands, by which the crystalline is suspended as by its opposite poles.

(1811.) Another peculiarity in the structure of the visual apparatus of osseous fishes is the existence of a vascular organ placed at the back of the eyeball, and interposed between the choroid tunic and a brilliant metallic-coloured membrane which invests the choroid externally. This organ, generally called the "choroid gland" by the older anatomists (fig. 321, A, *g g*), is of a crescentic form, and always of a deep-red colour. It is principally made up of blood-vessels, which run parallel to each other; and from it issue other vessels, frequently very tortuous, and always much ramified, which form a vascular network in the choroid. The nature of this organ it is not very easy to determine. Some have believed it muscular; but the striæ perceptible in it are vascular, and not fibrous: others have thought it to be glandular; but it has no excretory duct. Most probably it is an erectile tissue analogous to that of the *corpus cavernosum*, and has some influence in accommodating the form of the eye to distances, or to the density of the surrounding medium*.

(1812.) The pupil of the eye in the animals we are describing is very large, so as to take in as much light as possible, but generally motionless. In some genera the shape of the aperture is curious: thus in the Rays a broad palmate veil hangs in front of the pupillary aperture; and in one case, the *Anableps*, there are two pupils to each eye.

(1813.) The eyes of osseous fishes are lodged in the bony orbits of the face, imbedded in a soft glairy cellulosity; but in many of the cartilaginous tribes, such as the Sharks and Rays, each eyeball is moveably articulated to the extremity of a cartilaginous pedicle fixed to the bottom of the orbital cavity (figs. 322, *i*, & 321, C).

(1814.) Six muscles serve to turn the eye in different directions; namely, four *recti*, arising, as in Man, from the margin of the optic foramen; and two oblique muscles, derived from the anterior part of the orbit, and inserted transversely into the globe. These muscles are well represented in fig. 322, wherein the reader will observe that the superior oblique does not pass through a pulley, as is the case in the human subject.

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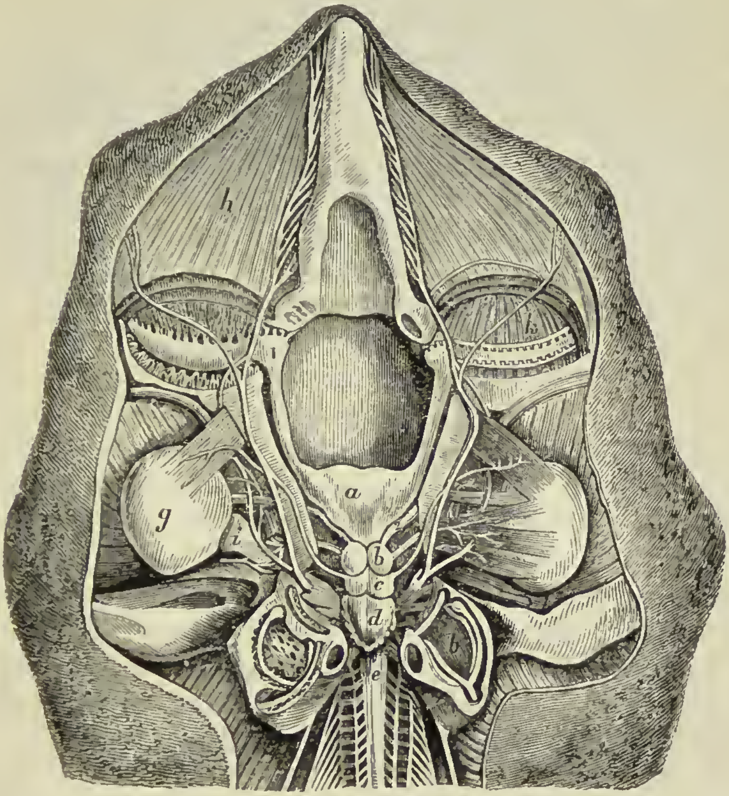
* Cuv. et Val. *op. cit.* p. 338.

Fig. 322.



Brain and cerebral nerves of the Skate: *a*, olfactory ganglion; *b*, *c*, cerebrum; *d*, cerebellum; *e*, medulla spinalis; *g*, the eyeball; *i*, its cartilaginous pedicle; *k*, olfactory sac; 1, distribution of the olfactory nerve.

(1815.) It is extremely remarkable that even in fishes the muscles of the eye have special nerves appropriated to them, and those precisely the same as in the highest Mammalia. The third pair of nerves animates them all, except the external rectus and the superior oblique, and also sends off filaments to be distributed to the choroid, although no ophthalmic ganglion has yet been discovered. The fourth pair is exclusively appropriated to the superior oblique; and the external rectus, or abductor muscle, invariably receives its supply from the sixth pair.

(1816.) To animals whose eyes are constantly washed by the water in which they live, any lacrymal apparatus would obviously be superfluous; and consequently, in the class before us, neither lacrymal gland nor lacrymal puncta, nor even eyelids, properly so called, are ever met with.

(1817.) Behind the optic lobes of a fish's brain the ganglia from which the other cerebral nerves emanate become confused into one mass, so that they are no longer distinguishable from each other. The nerves themselves, however, are easily recognized, and, with the exception of the ninth pair (the *lingual* or *hypoglossal* nerves), which are not met with in fishes, both in their distribution and number precisely accord with those with which the human anatomist is familiar. We have already traced the third, fourth, and sixth pairs to the muscles of the eye. The fifth issues through the great ala of the sphenoid, and divides, as in Man, into an ophthalmic branch (fig. 319, α), which runs through the orbit to be distributed to the parts about the nose; a superior maxillary branch (β), that supplies the parts about the upper jaw; and an inferior maxillary branch (θ), destined to the lower jaw: the general distribution of the nerve, as far as regards the face, is in fact exactly similar to that of the same nerve in Man; but in fishes it is found to give off other branches not met with in the human subject, one of which (μ) is destined to the operculum. Another (ξ) takes a very remarkable course: it mounts up to the top of the skull, joins a large branch of the eighth pair (Θ), and, issuing from the cranium through a hole in the parietal and interparietal bones, passes along the whole length of the back on each side of the dorsal fin, receiving twigs from all the intercostal nerves, and supplying the muscles of the fin and the fin-rays themselves.

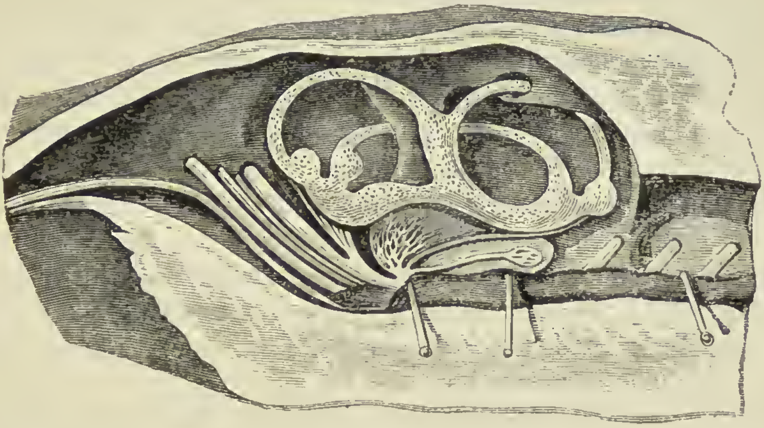
(1818.) This branch is superficial until it reaches the little muscles that move the fin. It has sometimes other branches, equally superficial, which descend to the anterior parts of the muscles of the trunk above the pectoral fins; and others which run as far as the anal fin, where they form a longitudinal nerve similar to that of the back.

(1819.) The seventh pair of cerebral nerves (fig. 319, *s s*), in fishes as in all other Vertebrata, is devoted to the organ of hearing, and brings to the sensorium the impressions of sound.

(1820.) The sense of hearing in these creatures must necessarily be very imperfect: they have neither an external ear nor a tympanic cavity, and consequently are entirely destitute of a *membrana tympani* and of the ossicles of hearing; they have neither Eustachian tube nor *fenestra ovalis*; the labyrinth alone, and that more simple in its composition than the labyrinth of the human ear, is all that the anatomist meets with in this first appearance of an auditory apparatus among the Vertebrate classes.

(1821.) The accompanying figure (fig. 323) represents the ear of a very large fish, the *Lophius piscatorius*; and the student will have little difficulty in at once recognizing all the parts of which it consists. The soft parts of this simple ear are not enclosed in bony canals, as in the human subject, but the membranous labyrinth is lodged in a wide cavity on each side of the cranium; so that little dissection is necessary to expose the entire organ, which is surrounded on all sides with the same kind of oily or mucilaginous fluid which fills up the wide interspace that exists between the brain and the dura mater lining the inner surface of the skull.

Fig. 323.



Auditory apparatus of the Skate.

(1822.) As in all other Vertebrata, there are three semicircular canals, disposed nearly as in the human ear, and each dilated in like manner into an ampulla which receives the filaments of the acoustic nerve. Two of the semicircular canals coalesce before they open into the vestibule, so that there are only five orifices whereby the three semicircular canals communicate with the vestibular cavity.

(1823.) The membranous vestibule (supported in the figure by two pins) is of variable shape, and its walls are very delicate. Its cavity, as well as the interior of the semicircular canals, is filled with a transparent glairy fluid; and it moreover encloses certain hard bodies (*otoliths*), generally three in number, suspended by delicate filaments in its interior.

(1824.) The *otoliths* of osseous fishes are of a stony hardness, resembling shell, and their structure is nothing at all like that of bone.

(1825.) Their shape varies in different species, but, nevertheless, is so constantly the same in fishes of the same kind, that the forms of these pieces might be employed as an important zoological character.

(1826.) In the cartilaginous fishes the *otoliths* are quite soft, resembling starch: in both classes they are composed principally of chalk, and effervesce strongly when dissolved in acids.

(1827.) The auditory nerve gives a filament to each of the semicircular canals, which penetrates into the ampulla of the canal to which it is destined, and there spreads out; but the larger portion of the nerve is distributed over the vestibular sacculus, where it forms a beautiful network.

(1828.) There is no *cochlea*, although some writers imagine that they can distinguish a rudiment of this part of the ear in a slight projection from the walls of the vestibule.

(1829.) The ears of fishes, therefore, are much less perfect than those of other Vertebrata*: deprived of tympanum, of ossicles, and of Eustachian tube, they can scarcely receive the impressions produced by the vibrations of the ambient element, except by those vibrations being communicated through the cranium; and moreover, the membranous labyrinth not being enclosed in bone, the skull can only transmit these movements in a very feeble and imperfect manner. The absence of a cochlea would go far to prove that the ear of fishes cannot appreciate the differences of tones. All that it offers to the physiologist is a membranous apparatus endowed with great sensibility, in which the nervous filaments distributed in the ampullæ of the semicircular canals must necessarily partake of all the movements of the fluid in which they are plunged, and where those appropriated to the vestibule must be still more strongly agitated by the shocks that these movements give to the *otoliths* contained in its cavities.

(1830.) It is probable, therefore, that fishes hear, that noise produces in them a powerful sensation, but that they cannot distinguish or appreciate differences of tone, as the higher animals are enabled to do.

(1831.) The nerves composing the eighth pair preside over the same functions in all the Vertebrata. The *glosso-pharyngeal* sends twigs to the first branchial arch, the fauces, and the tongue. The *nervus vagus* (fig. 319, *t*) supplies the three posterior branchiæ and the lower part of the pharynx; it is then continued along the œsophagus to the stomach, where it terminates: it thus presides over the same functions in all the Vertebrate classes; and it is not a little interesting to see it even in fishes distributed to the organs of respiration, notwithstanding the peculiarity of their structure and position. In these creatures, however, it likewise furnishes nerves to other parts of the body, especially a long branch, which generally runs in the substance of the lateral muscles of the trunk, communicating with the spinal nerves and giving off filaments to the skin—an arrangement the physiology of which is not as yet understood. The next pair of cerebral nerves in the animals under consideration would seem to represent the *spinal recurrent* of the human subject; it supplies the swimming-bladder and the muscles of the shoulder.

(1832.) All the above nerves posterior to the optic arise from a chain of ganglia constituting the *medulla oblongata*; but above these are situated other important masses entering into the composition of the encephalon, from which no nerves take their origin, viz. the *cerebral hemispheres* and the *cerebellum*.

(1833.) The cerebral hemispheres in all the Vertebrata are undoubtedly the seat of the mental powers; and as this portion of the brain becomes developed and perfected, brutality and stupidity give place to sagacity and intelligence.

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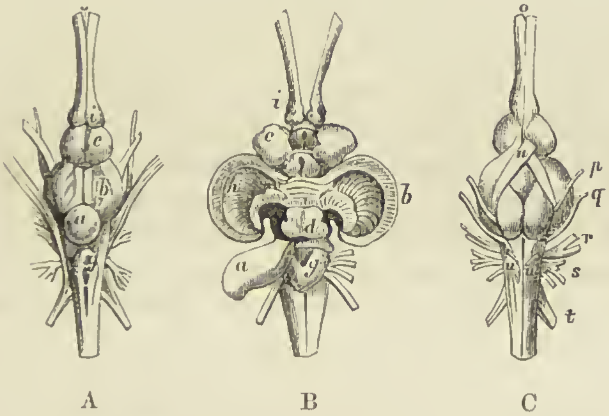
* Cuv. et Val. *op. cit.* p. 347.

(1834.) In the higher quadrupeds, and more especially in Man, the proportionate size of the hemispheres of the brain is so enormous that they overlap and conceal all the parts we have been describing; but as we descend to lower forms their relative dimensions become gradually smaller and their structure less complicated, until in fishes, the least intelligent of all the creatures belonging to this great division of the animal kingdom, they are found in such a rudimentary condition that they are frequently far inferior in size even to the olfactory or optic ganglia (fig. 322, *c*).

(1835.) The lobes representing the hemispheres in fishes (fig. 324, *b*) are quite smooth externally, and within are hollowed into a large ventricle, in the floor of which is seen the upper surface of the optic ganglia (fig. 324, B, *d*). They present none of that complication of parts met with in the brains of higher orders: their inner surface is lined with transverse fibres (*h*), and a simple commissure passes across the anterior part of the ventricle, bringing the two sides into communication with each other; behind the commissure a passage leads to the third ventricle, the infundibulum, and the pituitary gland.

Fig. 324.



Brain of the Perch (after Cuvier): *a*, cerebellum; *b*, cerebrum; *c*, olfactory ganglia; *i*, olfactory nerves; *d*, optic ganglia; *g*, supplementary lobe; *h*, transverse fibres in the walls of the cerebral ventricle; *n*, commissure of the optic nerves; *p*, *q*, *r*, *s*, *t*, *u*, the third, fourth, fifth, sixth, seventh, and eighth pairs of cerebral nerves.

(1836.) The *cerebellum* (fig. 324, *a*) is at once recognizable from its position and singleness. In the Perch its form is that of a blunted cone, with the summit directed slightly backward; but the shape and relative dimensions of this part of the brain are extremely variable. It consists, in fishes, only of the central portion (*processus vermiformis*), so that there are neither lateral lobes nor *pons Varolii*: its surface is composed of cineritious substance, and in its centre is a ramified medullary axis containing a ventricle.

(1837.) One very remarkable feature in the structure of the encephalon of fishes is the existence of supplementary lobes (fig. 324, *g*), placed behind the cerebellum, which are sometimes united by a commissure: occasionally, as in the *Trigla*, there are as many as five pairs of such supplementary masses; but probably, instead of regarding these as belonging to the brain, it would be more proper to consider them as being merely the first ganglia composing the spinal cord enormously developed in proportion to the importance of the nerves which they give off to the pectoral fins.

(1838.) The spinal nerves of fishes arise by double roots from the sides of the *medulla spinalis*, which generally extends from one end of the canal formed by the superior vertebral arches to the other. The posterior roots are dilated into ganglia soon after their origin, but the ganglia are extremely minute. The spinal cord of the Moon-fish (*Orthagoriscus Mola*) is, however, an exception to the usual conformation: in this remarkable fish the spinal ganglia are all collected into a stunted mass placed immediately behind the brain; and from this all the spinal nerves are given off, in the same manner as those forming the *cauda equina* in the human subject.

(1839.) The *sympathetic system* in the creatures we are now examining is of very small size when compared with that met with in the higher Vertebrata; nevertheless it occupies the usual position, and communicates, as in Man, with the commencements of the spinal nerves.

(1840.) There are few subjects more calculated to arrest the attention of the physiologist than the progressive development of the generative system in the Vertebrate classes; and it is not a little interesting to watch the gradual appearance of additional organs, both in the male and female, as we advance upwards in the series of animated beings from the cold-blooded and apathetic fishes. In its simplest condition, the whole generative apparatus, even of a vertebrate animal, is in both sexes merely a capacious gland provided with an excretory duct, wherein, in the female, ova are secreted, and in the male a fecundating fluid is elaborated from the blood. The eggs of the female, when mature, are expelled from the nidus in which they were formed, and cast out into the surrounding water. The male, urged apparently rather by the necessity of getting rid of a troublesome burden than by any other feeling, ejects the seminal secretion in the same manner; and the fecundating fluid, becoming diffused through the waves, vivifies the eggs with which it is casually brought into contact. Such is the whole process of reproduction in the osseous fishes.

(1841.) In the females of such fishes, the ovary, or roe, as it is generally called, consists of a wide membranous bag, ordinarily divided into two lobes, but sometimes, as in the Perch, single (fig. 317, *q*). This extensive organ, when distended with ova, fills a large proportion of the abdominal cavity; and its lining membrane is folded into broad festoons, wherein the ova are formed, and lodged until sufficiently mature for expulsion. When ripe, the eggs escape into the cavity of the ovary, and are expelled in countless thousands into the surrounding element through the orifice of the ovarian sac (fig. 317, *r*), which is situated immediately behind the anus (*k*) and in front of the urinary canal (*s*).

(1842.) Generally, as has been already stated, the ova of fishes are fecundated after their expulsion; but there are a few instances, as for example the Viviparous Blenny (*Zoarcus viviparus*) of our own shores, in which the young are hatched in the ovary, and grow to a considerable size before they are born: in such cases impregnation must take place internally; and the males in these species have, in fact, a nipple-like prolongation of the orifice of the duct through which the semen escapes, probably for the purpose of introducing the seminal fluid into the interior of the ovary of the females. Nevertheless even in these the ovaria present the same structure as in ordinary fishes,—the only difference being that their eggs are retained until the embryo is far advanced in its development, instead of being prematurely extruded.

(1843.) The testicle in the males of osseous fishes, generally named "the milt," equals in bulk the ovary of the other sex; and the quantity of the secretion furnished by it must be exceedingly great. The entire organ is composed of slender and very delicate convoluted cæca, in which the semen is elaborated. These tubes towards the circumference of the testis all terminate in blind extremities, but by their opposite ends they communicate with the general excretory duct; so that, by blowing air into the latter, the entire organ becomes amazingly distended. In some cases the seminiferous tubules run parallel to each other, and become furcate as they approach the exterior of the testis: in others, after dividing and subdividing to some extent, as they diverge from the common duct, they become converted into innumerable anastomosing ramifications; so that the whole substance of the testis appears to be made up of reticulate tubes, which during the spawning season, when they are filled with the creamy fluid that they secrete, are visible even with the naked eye*.

(1844.) It will be observed by the anatomical reader, that while in the OSSEOUS FISHES the ova escape into the interior of the ovary, and are expelled through an excretory orifice resembling the duct of an ordinary gland, in the CARTILAGINOUS FISHES and in all other VERTEBRATA the germs burst from the *exterior* of the ovarium, where they are generally seized by Fallopian tubes, and either conveyed out of the body as eggs, or, being hatched internally, the offspring are nourished in receptacles provided for the purpose, until they arrive at a considerably-advanced state of development.

(1845.) But it is only by degrees that these more perfect ovigerous organs make their appearance, and we would particularly solicit the attention of the student to the different gradations of structure met with in this part of the animal economy.

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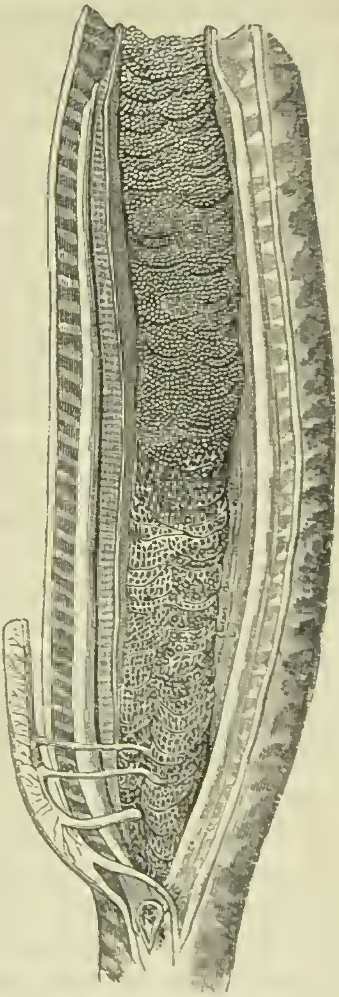
* Müller, De Glandularum Structurâ penitiori. Lipsiæ, fol. 1830.

(1846.) In the Eel and the Lamprey we have the first appearance of an ovary such as is common to the higher Vertebrata. It consists of a very extensive vascular membrane covered by the peritoneum, and attached in broad folds beneath the spine, extending nearly from one end of the abdomen to the other (fig. 325). This viscus is not hollow, neither has it any excretory duct; so that naturalists were long at a loss to explain how the ova of these creatures were expelled.

Fig. 325.



Reproductive organs of the Lamprey (*Petromyzon marinus*).

(1847.) The extensive membrane above alluded to, as is now sufficiently well determined, produces in its substance the germs of the future progeny; and these, as they become mature, break loose from the nidus wherein they were generated in the interior of the peritoneal cavity of the Eel, and float loosely in the abdomen. There is no Fallopian tube as yet developed; but two simple orifices, placed on each side of the anal opening, serve to give exit to the countless eggs which thus escape into the surrounding water.

(1848.) The male organs of the Lamprey and Eel, together with the ovaria of the female, and the kidneys and ureters, were accurately described by Hunter in the Catalogue of his Collection, and their form and structure are illustrated by the preparations and drawings still preserved in the College of Surgeons *; but in such fishes the testis of the male so exactly resembles the female ovary, that it was imagined even by Sir E. Home that no males existed, or that the females were themselves hermaphrodite. According to Rathke †, however, the testes of the male are composed of solid granules, precisely like the female ova; and the secretion derived from them is in like manner allowed to escape into the abdomen, from which it is expelled through similar openings in the peritoneum.

(1849.) In the Sharks and Rays we meet with a very important addition to the female sexual apparatus, namely, an *oviduct*, by which the germ is seized on its escape from the ovarium, and furnished with the additional covering necessary in such fishes for the security of tho fetus.

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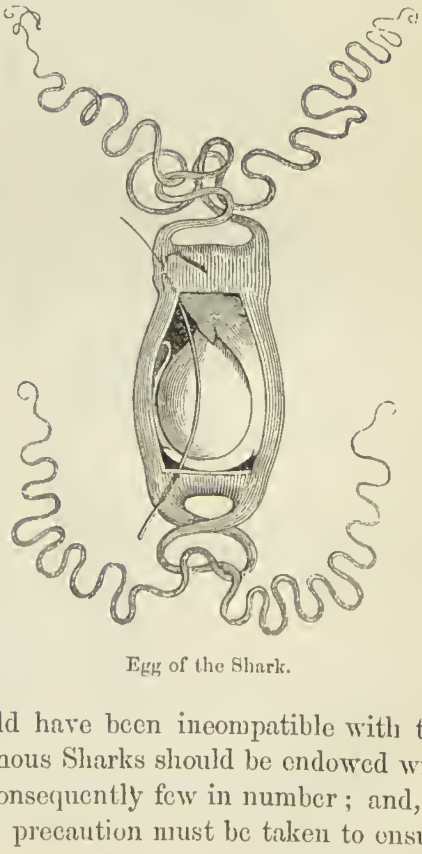
* See Physiological Catalogue, vol. iv. pp. 48, 129, pls. 59 & 60.

† Neueste Schriften der naturforschenden Gesellschaft zu Danzig. Halle, 1824.

(1850.) In these genera the folds of the ovarian membrane become less extensively spread out, and, from the size of the yelks of the eggs formed therein, the organ assumes a racemose appearance. The ovaries now form two large bunches placed on each side of the spine; and the ova when mature would necessarily escape into the abdominal cavity, as those of the Lamprey and Eel do, wero they not seized by the patulous orifices of the two long and membranous oviducts whereby they are conveyed out of the body.

(1851.) There is, moreover, in the CHONDROPTERYGIAN FISHES, a necessity for defending the young, during the earlier stages of their growth, by means which it would have been quite foreign to the purposes of Nature to have adopted in the other division of this extensive class. The earth is peopled only at its surface, and the vegetable banquet there spread is abundantly sufficient for the support of terrestrial beings. The ocean, however, being densely populated at every assignable depth, could never have supplied vegetable food to anything like the extent required to satisfy her progeny; hence therefore the necessity for that astonishing fertility so remarkable in the osseous fishes. Nine millions of ova have been calculated to be spawned at a birth by a single Cod-fish: such spawn, being naked and unprotected, is eagerly devoured by thousands of hungry mouths, or the feeble young soon fall a prey to countless voracious persecutors. If, however, it was obviously requisite that the progeny of osseous fishes should be thus multitudinous in order to provide a sufficiency of needful food, it is equally clear that it would have been incompatible with the design of the Creator that the ravenous Sharks should be endowed with equal fecundity: their eggs are consequently few in number; and, in proportion to their scarcity, jealous precaution must be taken to ensure the safety of the included young, in order to prevent the complete extinction of the race.

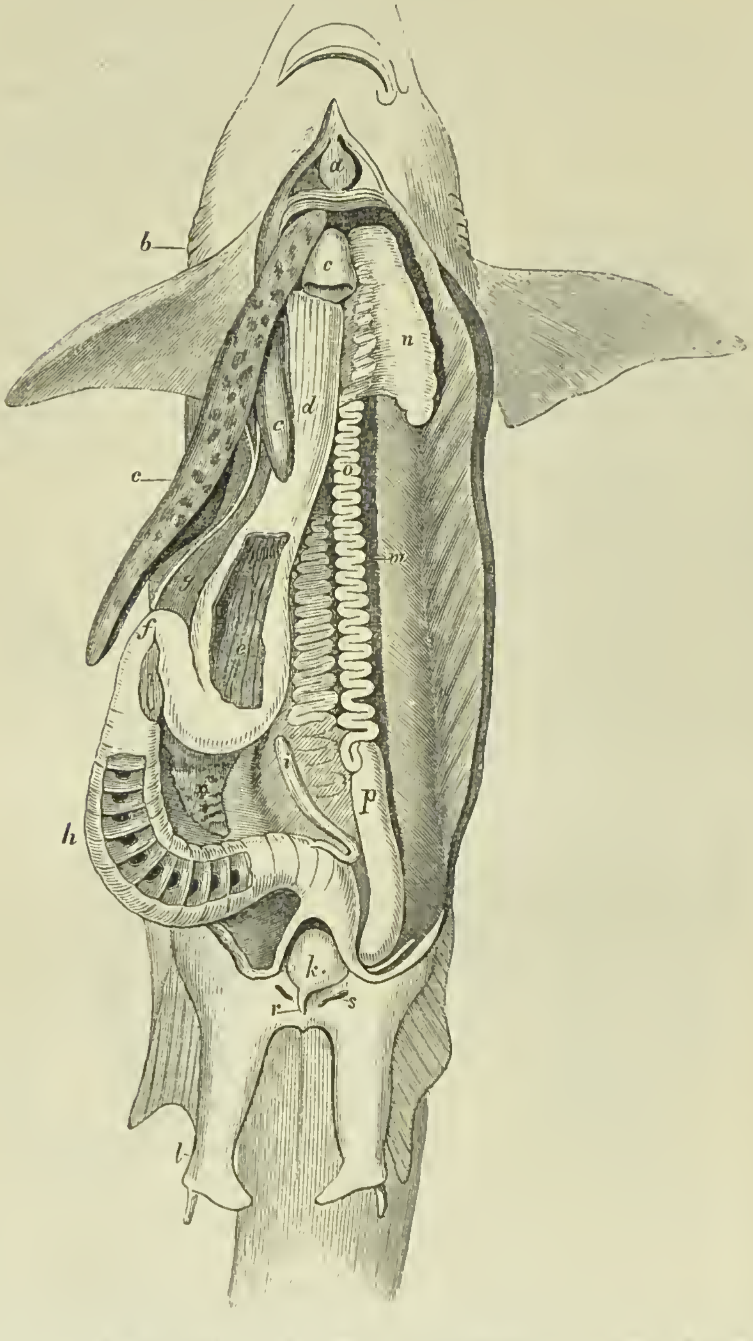
Fig. 326.



Egg of the Shark.

(1852.) The means employed for this end are simple and beautiful. About the middle of the oviduct of the female there is a thick glandular mass, destined to secrete a horny shell, in which the yelk and white of

Fig. 327.



Viscera of the Shark, *in situ*: *a*, the heart; *b*, gill-openings; *c c c*, lobes of the liver; *d*, *e*, *f*, *h*, alimentary canal; *i*, appendage to the intestine; *g*, biliary duct; *n*, the testis; *o*, *p*, vas deferens; *k*, intromittent organ; *r*, *s*, openings communicating with the peritoneal cavity; *l*, claspers.

the egg become encased. The egg when complete has somewhat the shape of a pillow-case, with the four corners lengthened out into long tendril-like cords (fig. 326), whereby the egg is entangled amongst the sea-weed at the bottom of the ocean. A brittle egg-shell would soon be destroyed by the beating of the waves; hence the necessity for the corneous nature of the envelope; and yet, how is the feeble embryo to escape from such a tough and leather-like cradle? This likewise has been provided for: the egg remains permanently open at one extremity, or, to carry out our humble simile, one end of the pillow-case is left unsewn; the slightest pressure from within, therefore, separates the valvular lips of the opening; and no sooner has the little Shark thus extricated itself from its confinement than the two sides close again so accurately that the fissure is not at all perceptible *.

(1853.) The sexual organs of the male Chondropterygii are very remarkable, and their real character is not properly understood. The testicle (fig. 327, *n*) is large, and occupies the same position as the ovary of the female; but the singularity of this testis consists in its being made up of two portions, one of which has an excretory duct, while the other, although equally bulky, has none.

(1854.) The former portion, when minutely examined, is composed of an immense assemblage of flexuous secerning vessels, that pour their secretion into a long and tortuous vas deferens (*o*), which, after running in a zigzag course nearly the whole length of the abdomen, dilates into a capacious reservoir of semen (*p*), and ultimately terminates with its fellow of the opposite side in a conical fleshy organ (*k*), which may be presumed to answer the purpose of an intromittent apparatus.

(1855.) The second portion of the testis appears to consist of globular bodies having no excretory duct whatever; and it is not impossible that this is an organ analogous to the testis of the Lamprey, and that its secretion escapes into the abdominal cavity, to be expelled through two orifices (*s s*) situated on each side of the anus, whereby a free communication exists between the interior of the peritoneal sac and the external surface of the body.

(1856.) In these highly-organized genera impregnation takes place internally, and the male is furnished with two strong prehensile organs called *claspers* (*l*), by means of which he seizes and securely holds the female during copulation.

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* According to Cuvier, in those Sharks which are viviparous (that is, whose young are hatched in the oviduct prior to their expulsion) this egg-shell is never formed, and the investments of the fœtus remain permanently membranous (*loc. cit.* p. 397).

CHAPTER XXVII.

REPTILIA.

(1857.) The globe that we inhabit is usually said to be made up of land and water; and perhaps, for the purposes of the geographer, such a division of the surface of our planet is all that is requisite. A slight investigation of this subject, however, is sufficient to convince the naturalist that a very considerable proportion of the world around us can scarcely be strictly referred to either one or the other of the geographical sections alluded to,—that there are extensive marshes, for instance, equally ill-adapted to be the habitation of aquatic animals and of creatures organized for a purely terrestrial existence; that some localities may be alternately deluged with water and parched with drought; that the margins of our lakes, the banks of our rivers, and the shallow ponds and streamlets of warm climates could only be adequately populated by beings of an amphibious character, alike capable of living in an aquatic or in an aërial medium, and combining in their structure the conditions necessary for enabling them to reside in either element.

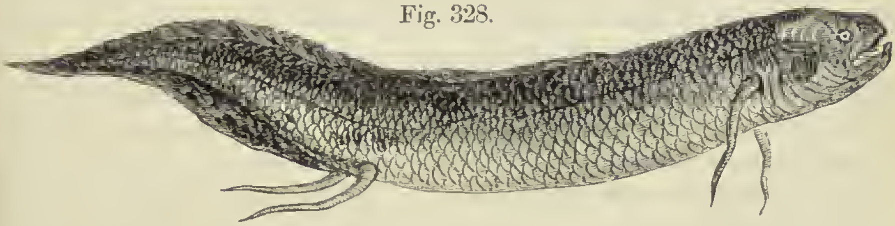
(1858.) Aquatic animals, strictly so called, breathe by means of gills. For a vertebrate animal to respire air, it must be provided with lungs; but if a creature is destined to live both in air and water, it must obviously have both gills and lungs coexistent, either of which may be employed in conformity with the changing necessities and altered circumstances. We therefore cannot be surprised to find that in the lowest Reptiles this is literally the arrangement adopted—that they respire, like fishes, by means of branchiæ while in the water, whereas on emerging into the air they have lungs ready for use.

(1859.) The Amphibia (*Batrachia*, Cuv.) are to the anatomist amongst the most interesting animals in the whole range of zoology, as we trust will be made sufficiently evident when we come to investigate their internal economy; but it is to their outward forms and habits that we must first introduce the reader, leaving the details of their organization to be discussed in the sequel.

(1860.) From whatever form or race of animals the zoologist advances towards the next succeeding it in the great scale of Nature, he will find himself insensibly led on by such gentle gradations that the transition from any one class to another is almost imperceptible. *Nihil per saltum* is one of the most obvious laws in creation; and of this, perhaps, we could not select a more striking illustration than is afforded by the *Lepidosiren* (fig. 328).

(1861.) Two distinct species of this most remarkable animal have been met with: one, the *Lepidosiren paradoxa*, discovered by Dr. Natterer in the river Amazon; the other, *Lepidosiren annectans*, was found by T. C. B. Weir, Esq., and is a native of the African continent, inhabiting the river Gambia. An individual of the species last mentioned has been minutely anatomized by Professor Owen*, and both in its outward form and internal organization is so precisely intermediate between a Reptile and a Fish, that, while Dr. Natterer regards it as an Amphibian, Professor Owen considers that, notwithstanding that it possesses lungs, the ichthyic characters predominate, and it ought rather to be ranked among the Fishes.

Fig. 328.



Lepidosiren annectans.

(1862.) The body of the *Lepidosiren annectans* (fig. 328) is about a foot long, and covered with scales, resembling those of the cycloid fishes; the tail gradually tapers to a point, but is fringed above and below with a membranous fin supported by numerous soft, elastic, transparent rays, articulated to the superior and inferior spines of the caudal vertebræ; the gills are covered by opercula—not being exposed, as in the proper Amphibia; and, moreover, it has four rudimentary fins or legs, as the reader may choose to call them. These rudimental extremities are round, filiform, and gradually attenuated to an undivided point, being supported internally by a single-jointed soft or cartilaginous ray. The nostrils of the Lepidosiren, however, are merely two blind sacs, as in fishes, and do not communicate with the mouth or fauces—a character which Professor Owen regards as the only decided evidence that the animal ought in preference to be ranked among the class Pisces.

(1863.) The *Siren lacertina*, a creature which inhabits the marshes of Carolina, is another amphibious animal, scarcely further removed from the Fishes than the last. This Siren attains the length of two or three feet; it has a body very nearly resembling that of an eel; but instead of pectoral fins it has two rudimentary feet, each provided with four fingers,—its hind feet, the representatives of the ventral fins, being entirely wanting; it is moreover furnished with gills placed on each side of the neck, while internally it possesses two capacious membranous lungs adapted to aërial respiration.

(1864.) In the *Proteus anguinus*, an animal only met with in the subterranean waters of Carniola, the body, of which a figure is given in a subsequent page (fig. 340), is equally anguilliform; but the legs are now four in number, although still very imperfectly developed. Its gills are fringes of blood-vessels placed externally upon the sides of the neck, and its thin and delicate lungs (t, z) extend nearly the whole length of the abdomen.

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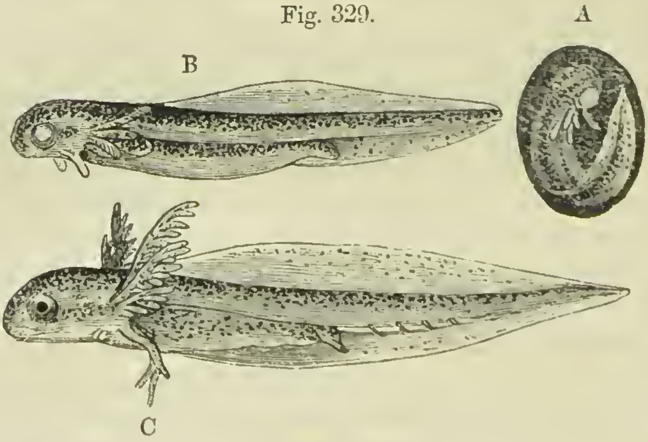
* Transactions of the Linnean Society for 1840.

(1865.) The Amphibia above-mentioned, as well as the *Menobranchus* and the *Axolotl*, both animals of very similar construction, preserve their branchiæ through the whole period of their lives, and are for this reason denominated *Amphibia perennibranchiata*. But there are other genera which, although in the early part of their existence they are equally provided with both gills and lungs, ultimately become sufficiently perfect in their organization to enable them to enjoy a more or less complete terrestrial existence, and consequently their branchiæ become obliterated as the lungs grow more efficient, until at length no vestiges of the former remain perceptible. These are called *A. caducibranchiata*.

(1866.) The most remarkable examples of the CADUCIBRANCHIATE AMPHIBIA are the Frogs, the Toads, and the Newts, so common in our own country; and the metamorphosis of these creatures from the *tadpole-* or fish-condition under which they leave the egg, to their perfect air-breathing and four-footed state, is a matter of common observation. We select the Newt (*Triton cristatus*) as an example of the changes which these amphibians undergo as they advance towards maturity.

(1867.) Immediately before leaving the egg, the tadpole of the Salamander, or Water-Newt (fig. 329, A), presents both the outward form and internal structure of a fish. The flattened and vertical tail fringed with a broad dorsal and anal fin, the shape of the body, and the gills appended to the sides of the neck are all apparent; so that, were the creature to preserve this form throughout its life, the naturalist would scarcely hesitate in classing it with fishes properly so called.

Fig. 329.

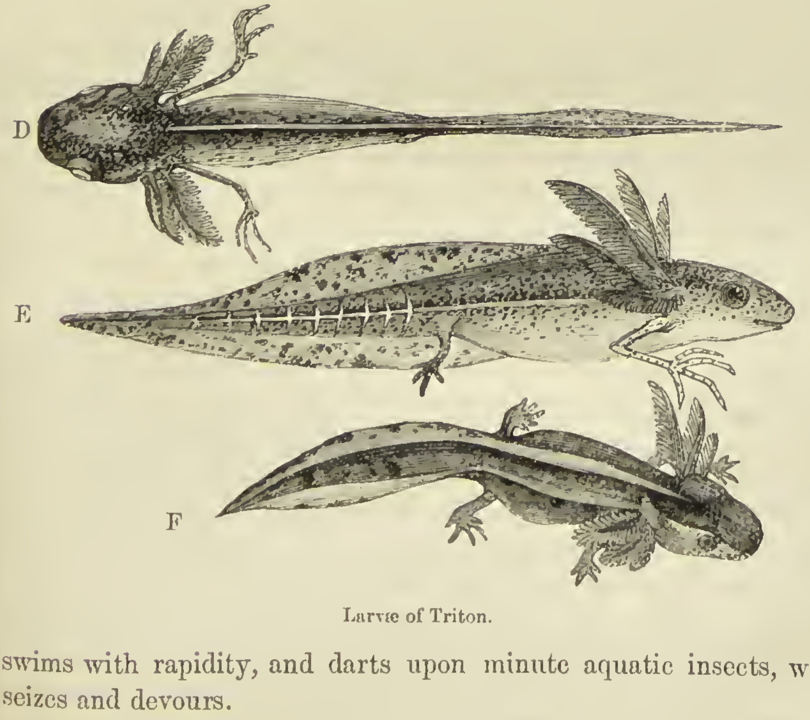


Larvæ of Triton.

(1868.) When first hatched (fig. 329, B)*, it presents the same fish-like body, and rows itself through the water by the lateral movements of the caudal fin. The only appearance of legs as yet visible consists in two minute tubercles, which seem to be sprouting out from the skin immediately behind the branchial tufts, and which are, in fact, the first buddings of anterior extremities. Nevertheless, to compensate to a certain extent for this total want of those prehensile limbs which afterwards become developed, two supernumerary organs are provisionally furnished, in the shape of two minute claspers, seen in the figure, situated on each side of the mouth; by means of these the little being holds on to the subaquatic leaves, and thus prevents itself from being washed away by the slightest current.

(1869.) Twelve days after issuing from the egg, the two fore legs, which at first resembled two little nipples, have become much elongated, and are divided at their extremity into two or three rudiments of fingers (fig. 329, e). The eyes, which were before scarcely visible, and covered by a membrane, distinctly appear. The branchiæ, at first simple, are divided into fringes, wherein red blood now circulates; the mouth has grown very large; and the whole body is so transparent as to reveal the position of the viscera within. Its activity is likewise much increased; it swims with rapidity, and darts upon minute aquatic insects, which it seizes and devours.

Fig. 330.



Larvæ of Triton.

(1870.) About the twenty-second day (fig. 330, D) the Tadpole, for the first time, begins to emit air from its mouth, showing that the lungs have begun to be developed. The branchiæ are still large. The fingers upon the fore-legs are completely formed; the hind-legs begin to sprout beneath the skin; and the creature presents, in a transitory condition, the same external form as that which the *Siren lacertina* permanently exhibits.

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* *Vide* Rusconi, Amours des Salamandres aquatiques, et Développement du Têtard de ces Salamandres depuis l'œuf jusqu'à l'animal parfait. 4to. Milan, 1821.

(1871.) By the thirty-sixth day the young Salamander (fig. 330, E) has arrived at the development of the *Proteus anguinus*; its hind-legs are nearly completed, its lungs have become half as long as the trunk of its body, and its branchiæ more complicated in structure.

(1872.) At about the forty-second day the Tadpole begins to assume the form of an adult *Triton* (fig. 330, F): the whole body becomes shorter; the fringes of the branchiæ are rapidly obliterated, so that in five days they are reduced to simple prominences covered by the skin of the head; and the gill-openings at the sides of the neck, which, as in fishes, allowed the water to escape from the mouth, and were in like manner covered with an operculum formed by a fold of the integument, are gradually closed; the membranous fin of the tail contracts, the skin becomes thicker and more deeply coloured, and the creature ultimately assumes the form and habits of the perfect Newt, no longer possessing branchiæ at all, but breathing air, and in every particular completely converted into a reptile.

(1873.) But however curious the phenomena attending the development of the tadpoles of the amphibious Reptiles may be to the observer who merely watches the changes perceptible from day to day in their external form, they acquire a tenfold interest to the physiologist who traces the progressive evolution of their internal viscera—more especially when he finds that in these creatures he has an opportunity afforded him of contemplating (displayed before his eyes, as it were, upon an enlarged scale) those phases of development through which the embryo of every air-breathing vertebrate animal must pass while concealed within the egg. The division, therefore, of Reptiles into such as undergo a metamorphosis, and such as do not, is by no means philosophical, although convenient to the zoologist: all Reptiles undergo a metamorphosis, though not to the same extent. In the PERENNIBRANCHIATA the change from the aquatic to the air-breathing animal is never fully completed; in the CADUCIBRANCHIATA the change is accomplished after the embryo has escaped from the ovum; and in the REPTILIA proper, as well as in BIRDS and MAMMALS, which are generally said to undergo no metamorphosis, the changes referred to are accomplished *in ovo* during the earliest periods of the formation of the fœtus.

(1874.) The second order of Reptiles (OPHIDIA) includes the Serpent tribes, animals entirely deprived of external locomotive extremities, and nevertheless endowed with attributes at once formidable and surprising. Absolutely without limbs or any apparent means of progression, the scale-clad serpent makes its way in either element with equal facility, and walks or leaps, or climbs or swims, at will. Destitute of any prehensile members, it seizes and devours the strongest and most active prey: it binds its victim in a living rope; or, with a single scratch inflicted by its venomed fangs, speedily destroys the stoutest assailant.

(1875.) The transition from the OPHIDIA to the Lizards (SAURIA), composing the third order of Reptiles, is very gradually accomplished by several intermediate forms, in which the first buddings of legs make their appearance; and these locomotive organs, becoming more and more completely developed in other genera, at length conduct us from the flexible and apodous Serpents to the strong and four-footed Reptiles which are the types of the Saurian division. The progressive development of the locomotive extremities is not a little curious: even among some of the Serpents properly so called, as, for example, in the *Anguis fragilis* of our own country, the rudiments of these limbs may be detected beneath the skin; more especially those of the hinder extremity, wherein a little *pelvis* and *femur* may be distinctly recognized, while a minute *sternum, clavicle,* and *scapula* indicate the first appearance of the thoracic legs.

(1876.) In *Bimanes,* the lowest of the Saurian genera, two little feet, each provided with four toes, are appended to the framework of the shoulder; and in *Seps,* which equally possesses the body of a serpent, all four extremities first make their appearance externally. As the legs become increased in their relative size and importance, the trunk is proportionately shortened and its flexibility diminished, until at length we are conducted, almost by imperceptible gradations, to the strong and voracious Crocodiles, the most perfect of the Reptile families.

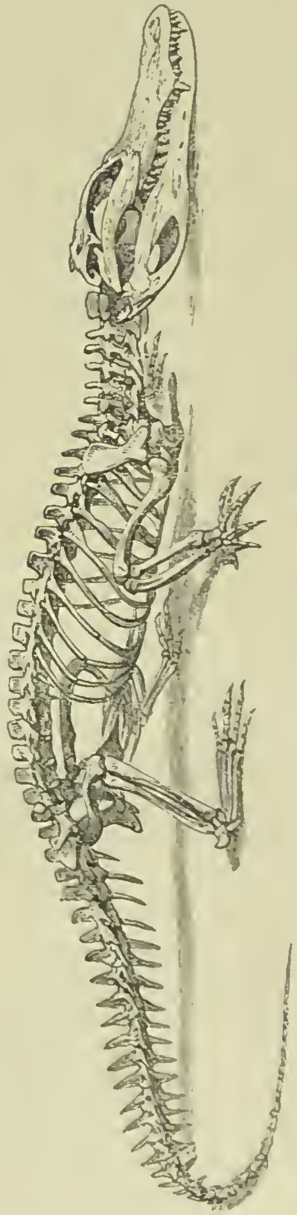
(1877.) The fourth order of Reptiles (CHELONIA) comprises a series of animals of most anomalous conformation, in which the greater part of the skeleton is brought quite to the exterior of the body, and the limbs are absolutely enclosed within the cavity formed by the ribs. Such are the Tortoises and the Turtles; but as we shall describe the anatomy of these animals more at length hereafter, we need only in this place point out to the reader their outward form and general appearance.

(1878.) Commencing our researches concerning the internal organization of this extensive class by examining the osteology of the Reptilia, we shall, as we have hitherto done, select one skeleton for special examination; and afterwards, taking that as a standard of comparison, observe the most conspicuous modifications of structure met with in the different divisions of this important group.

(1879.) The skeleton we choose for particular description is that of the *Crocodile,* one of the most interesting that can possibly be offered to the contemplation of the comparative anatomist, inasmuch as it exhibits, developed to a medium extent, a greater number of the elements which we have supposed to enter into the composition of a perfect or typical skeleton than any other with which we are acquainted: we therefore beg the attention of the student while we investigate this important piece of osteology.

(1880.) A glance at the skeleton of the Crocodile (fig. 331) at once shows us that, in consequence of the addition of a thorax, and the connexion which now necessarily exists between the pelvis and the spine, the vertebral column becomes divisible into distinct regions: viz. the *cervical*, containing seven vertebræ; the *dorsal*, formed by those vertebræ which support the thoracic ribs; and the *lumbar* vertebræ intervening between these and the *sacrum*. The number of bones entering into the composition of the *sacrum*, that is, which are connected with the *ossa ilii* of the pelvis, are in this case two in number; while, behind these, six-and-thirty vertebræ enter into the composition of the tail.

Fig. 331.



Skeleton of the Crocodile.

(1881.) In the cervical, dorsal, lumbar, and sacral regions, no inferior spinous processes exist; but in the caudal portion of the vertebral column these elements are found greatly developed, as in fishes, and obviously with the same intention, namely to increase as much as possible the vertical extent of the tail, and thus convert this part of the body, which is here of extraordinary length and great flexibility, into a powerful instrument of propulsion.

(1882.) The transverse processes of the cervical vertebræ are remarkably large, and so extended that they materially interfere with the lateral movements of the neck,—an arrangement evidently designed to afford a sufficient extent of insertion for the powerful muscles of the cervical region.

(1883.) The thorax is composed of a *sternum* and two sets of ribs,—one set being articulated with the transverse processes of the dorsal vertebræ, and hence called dorsal ribs, while the others, being fixed to the sides of the sternum, are named sternal ribs: the contiguous extremities of the dorsal and sternal ribs are, moreover, united by intervening cartilages, which, as they are generally more or less perfectly ossified in the adult Crocodile, might almost be regarded as additional elements of the thorax.

(1884.) The posterior dorsal ribs are far less perfectly developed than those situated more anteriorly; and it is not a little interesting to observe how gradually, even in the same skeleton, the transition is effected from the simple condition already noticed in the ribs of fishes, in which each rib is merely appended to the extremity of the transverse process of a vertebra, to ribs perfectly adapted to enter into the composition of a true thoracic cavity, and united by a double articulation both with the transverse processes and the bodies of the vertebræ. The head of the last rib of the Crocodile is, in fact, simple, and merely articulated with the apex of the transverse process of the corresponding vertebra; the next is slightly bifid at its origin, but both the divisions are still connected with the transverse process; as we advance still further forwards, the division of the origin of the rib becomes more and more decided, until at length, at about the fifth rib, we have two distinct heads, one firmly articulated with the body of the vertebra, the other with the transverse process—presenting an arrangement precisely similar to that met with in the structure of the thorax of a bird.

(1885.) The sternal apparatus is not less interesting to the osteologist. The anterior extremity of the sternum is osseous, and considerably prolonged forwards, to be articulated with the clavicles, and thus afford a support to the anterior extremity. Behind this it becomes cartilaginous, and affords attachment to the sternal ribs, which enter into the composition of the thorax: it does not, however, terminate at the posterior margin of the thoracic cavity, but is continued along the mesial line of the abdomen quite to the pubis, and gives off eight *abdominal sternal ribs,* to which no dorsal correspondents are met with. These abdominal ribs serve to support the muscles of the abdomen, and here present their *maximum* of development: rudiments of them are, however, still met with in the higher animals; and even in the human subject we find, in the transverse tendinous bands which intersect the substance of the *rectus* muscle of the abdomen, the last remains of these appendages to the sternal portion of the skeleton.

(1886.) In the anterior extremity of the Crocodile we have most of the parts enumerated as entering into the composition of a perfect or typical skeleton: the shoulder, however, is composed of only two pieces, the *scapula* and the *clavicle,* the last of which articulates with the sternum; the bones of the arm, fore-arm, and hand are completely developed.

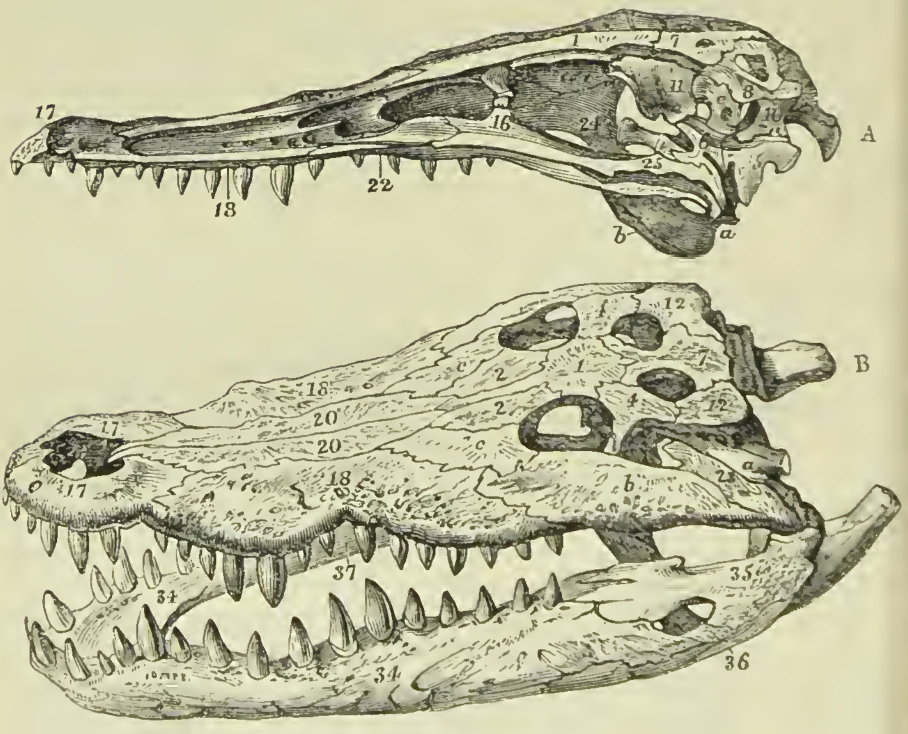
(1887.) The posterior extremities are fully formed, the pelvis being connected by means of the *ossa ilii* to the transverse processes of two vertebræ, which therefore, as we have seen, constitute the *sacrum.*

(1888.) In examining the bones which enter into the composition of the head of the Crocodile, or indeed of most Reptiles, the anatomist finds his studies much facilitated by the circumstance that the sutures separating the individual bones never become obliterated, so that the elements of this portion of their skeleton remain permanently detached and separate; and for this reason we shall take the present opportunity of going a little into detail concerning the composition of the skull of the Crocodile, as it is well calculated to illustrate the real structure of the cranium in the Vertebrata generally.

(1889.) The bones belonging to the face are easily recognized: the *intermaxillary* (17), the *maxillary* (18), and the *nasal* (20), the *zygomatic* (*b*), and the *lacrymal* (*c*), all occupy their usual relative positions. The roof of the mouth is formed, as in Man, anteriorly by an elongated process of the upper jaw (18), and posteriorly by the palate-bone (22).

(1890.) The *frontal* consists of five pieces, viz. the *principal frontal* (1), which probably, in the fœtus, consisted of two lateral halves, the *anterior frontal* (2, 2) and the *posterior frontal* (4, 4).

Fig. 332.



Skull of the Crocodile.

(1891.) The *parietal* (7) is, as is generally the case in Reptiles, represented by a single bone.

(1892.) The *occipital* consists of four pieces, which remain permanently detached; namely, the *basilar* (5), the two *lateral occipital* (10), and the *superior occipital*, placed above the *foramen magnum*.

(1893.) The *sphenoid*, which in Man is regarded as a single bone, is here represented by several distinct parts. The body is divided into two portions (6), called respectively the *anterior* and the *posterior sphenoids*. The great or *temporal alæ* (11) are also separate bones, as also are the *internal pterygoids* (25).

(1894.) A bone (24), which is not met with either in Mammalia or Birds, passes from the *internal pterygoid* to the point of junction between the *zygomatic*, the *maxillary*, and the *posterior frontal*: this has been named by Cuvier the *transverse bone*.

(1895.) The *ethmoid* and the *vomer* (16) are but very imperfectly ossified, so that the septum between the nostrils is in the skeleton extremely incomplete, and the sense of smell of course proportionately obtuse.

(1896.) But the most interesting of the cranial bones is the *temporal*, which, although considered as one bone by the human osteologist, is in Reptiles evidently composed of at least four distinct and separate parts. These are, 1st, the *petrous bone* (fig. 332, A, *e*), which partially encloses the organ of hearing; 2ndly, the *tympanic bone* (*a*), which supports the membrana tympani; 3rdly, the *mastoid bone* (12), which is the homologue of the mastoid process of Man; and 4thly, the *temporal bone*, properly so called (23), which represents the squamous portion of the human temporal bone.

(1897.) Each lateral division of the inferior maxilla of Reptiles is separable into at least five, and generally six pieces, which are united together by suture; these are named the *dental* (34), which support the teeth, the *angular* (36), the *opercular* (37), the *articular* (35), and two small pieces seen upon the inner surface of the jaw.

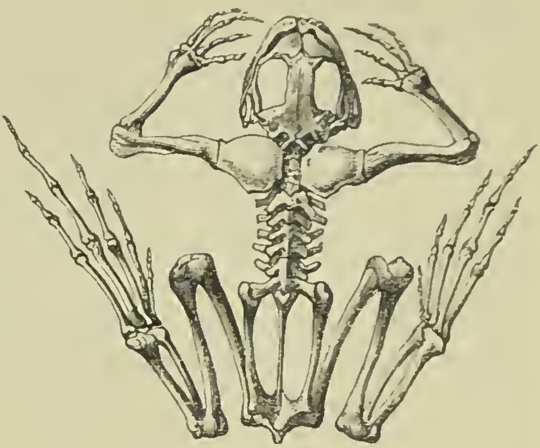
(1898.) Having thus described at some length the composition of the skeleton in the Crocodile, which we have chosen for minute analysis, as being the type of the Saurian Reptiles, we shall now proceed to examine the osteology of the other orders, so as to appreciate more correctly the peculiarities of structure that they individually exhibit.

(1899.) In the AMPHIBIA, as for example in the *Frog*, one of the most striking circumstances connected with their history is the extraordinary change which takes place in the condition of every part of the framework of the body during the evolution of the tadpole and its metamorphosis into the perfect frog.

(1900.) The skeleton of a Tadpole is, in every particular, that of a fish: its texture is soft and cartilaginous, the caudal portion of the spine prolonged and flexible; neither are there any external limbs connected with the vertebral column, so as to trammel the lateral movements of the tail; and yet in the mature Frog (fig. 333) let the reader observe the amazing difference. The head, it is true, still preserves somewhat of the character of that of the fish, especially in the disproportionate development of the face when compared with the size of the cranial cavity;

but all the bones of the spine have become consolidated into ten vertebræ, firmly connected together by strong articulations, while the flexible tail of the tadpole has become converted into a strong and immoveable *os coccygis*, composed of a single piece.

Fig. 333.



Skeleton of the Frog.

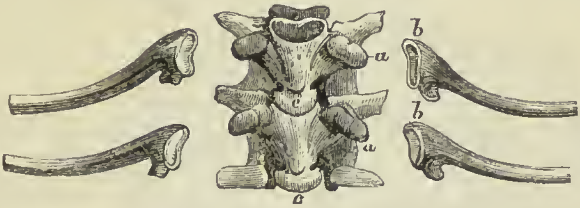
(1901.) No ribs whatever are met with in the Frog; and even in those Amphibia which are possessed of these elements of the skeleton, they are mere rudiments appended to the extremities of the transverse processes of the vertebræ. The sternum, however, is largely developed, and gives extensive attachment to the muscles of the abdomen. The anterior extremities are supported by a semicartilaginous zone, in which the three elements of the shoulder (the scapula, the clavicle, and the coracoid bone) are distinctly recognizable; and the bones of the arm, fore-arm, and hand are very perfectly formed.

(1902.) The *pelvis* is large and firmly ossified, in correspondence with the strength and magnitude of the hinder extremity, the *ossa ilii* being articulated to the ends of the transverse processes of the last vertebra, which from this circumstance may be called the *sacrum*. The *tibia* and *fibula* are consolidated into one bone; while two of the bones of the tarsus (the *astragalus* and the *os calcis*) are so excessively elongated that they might almost be taken for a second tibia and fibula, did not their position indicate their real nature.

(1903.) One circumstance is remarkable in the construction of the shoulder-joint of these reptiles, which are found to have a strong ligament passing between the head of the humerus and the scapula, exactly in the same manner as the *ligamentum teres* of the human hip-joint. The use of such a deviation from the ordinary structure of the articulation is obvious: the Frog, as it alights from those long and vigorous leaps which form its ordinary mode of progression, receives the whole shock of its fall upon its fore-legs, and thus this ligament becomes needful as an additional security to the articulation in question.

(1904.) The skeleton of an Ophidian Reptile presents a strange contrast to that of the Batrachian, last described. Taking the *Boa Constrictor* as an example of this order, we find the spine of this enormous serpent composed of three hundred and four distinct vertebræ, of which two hundred and fifty-two support ribs: flexibility is therefore abundantly provided for in the construction of these lithe and elegant beings, inasmuch as the division of their spinal column into so many pieces allows the utmost pliancy in any required direction. Flexibility, however, is not the only condition requisite in this case: strength and precision of movement are equally indispensable; and the question is, how are these apparently opposite qualities to be so combined and associated as not in the slightest degree to interfere with each other? The mechanism conspicuous in the construction of the spine of a Serpent is in this respect truly admirable. The anterior extremity of the body of every vertebra is rounded into a smooth and polished ball (fig. 334, *c*), which exactly fits into a hemispherical cup excavated in the substance of the vertebra next succeeding: a perfect ball-and-socket joint is thus formed between every vertebra and that which precedes or follows it; and thus the spine is rendered capable of the utmost latitude of movement, and offers at the same time a firm purchase to the muscles acting upon the vertebral column. To provide, however, against undue extent of motion in certain directions, we now meet with other processes derived from the vertebral arches: in addition to those given merely as levers for the attachment of muscles, secondary apophyses, called *oblique* or *articulating processes*, become developed; and contiguous vertebræ being likewise moveably connected together by means of these appendages, unnecessary flexure is not allowed, and all danger of dislocation prevented.

Fig. 334.



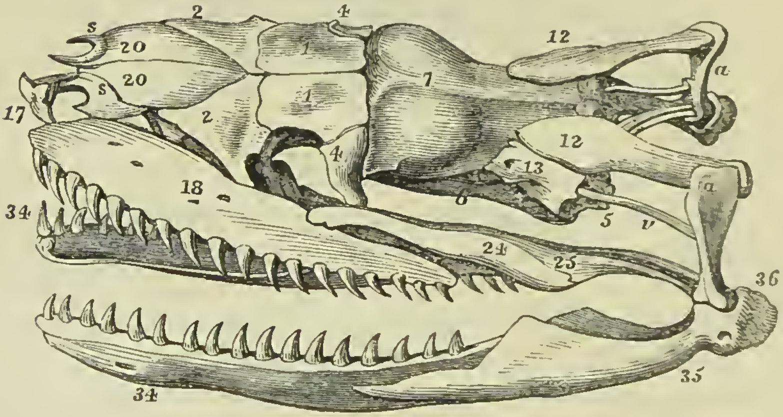
Vertebræ and Ribs of *Boa*.

(1905.) Serpents, being entirely deprived of external limbs, have neither shoulder nor pelvis, their ribs alone affording them the means of progression. These extend on each side in an uninterrupted series from the first vertebra behind the head to the origin of the tail, so that the division of the spine into regions is here out of the question. Every rib is attached at its origin by a kind of ball-and-socket joint (fig. 334, *a*, *b*) to the extremity of the corresponding transverse process of a vertebra, and is therefore freely moveable. There is no sternum here, neither are there sternal ribs; but the dorsal ribs, wielded as they are by innumerable and powerful muscles connected with them, literally perform the office of internal legs, and materially assist the creature in progression.

(1906.) Having already enumerated the bones which enter into the composition of the cranium of a Saurian Reptile, it would be superfluous again to mention in detail those met with in the skull of a Serpent, more especially as they will be easily recognized by a glance at the annexed figure, in which the corresponding bones are all indicated by the same references. One peculiarity only requires special notice, namely the extreme mobility of the principal bones of the face, and more particularly of the pieces composing the lower jaw, by which provision these reptiles are enabled to swallow entire animals of astonishingly large dimensions when compared with the size of their mouth.

(1907.) In order to allow of this, the bones composing the superior maxilla (fig. 335, 17, 18) are only loosely joined together by ligamentous bands; and even the arches of the palate are moveable. The two halves of the lower jaw (34, 34) are connected together at the symphysis by a ligament so loose and elastic that separation to a great extent is easily allowed; and, moreover, those two elements of the temporal, the *mastoid* (12) and the *tympanic* (*a*), which form the bond of connexion between the inferior maxilla and the cranium are here lengthened out into long pedicles, so that by their mobility the entrance to the throat can be dilated in a surprising manner, and prey of apparently very disproportionate bulk thus introduced into the stomach.

Fig. 335.

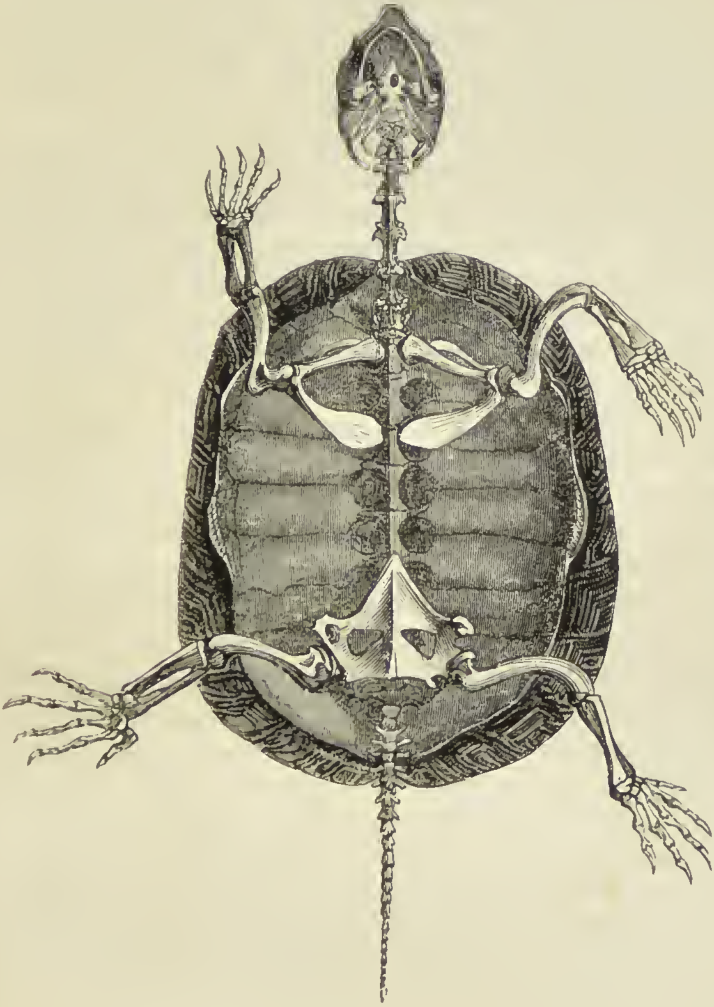


Skull of *Boa*.

(1908.) The most extraordinary skeleton met with among Reptiles, and, indeed, among the Vertebrata generally, is that of the CHELONIA, in which the ribs and sternum are both placed quite at the exterior of the body, so as to form a broad dorsal shield called the *carapax*, and an equally strong ventral plate named the *plastron*, between which the limbs and the head can be more or less completely retracted.

(1909.) Yet notwithstanding this apparent total inversion of the osseous system in the creatures before us, it is interesting to observe by what slight modifications in the arrangement of the elements of the skeleton such prodigious changes are accomplished. This is well exemplified in the construction of the *carapax* of the common Tortoise (*Emys Europæus*). In this well-known animal (fig. 336) the vertebræ of the

Fig. 336.



Skeleton of Tortoise.

neck and of the tail present nothing particularly remarkable in their structure; but, being connected together in the ordinary manner, the neck and caudal region of the spine present their usual flexibility. The dorsal vertebræ, however, are strangely distorted, the elements of the upper arch being disproportionately developed, while the bodies remain almost in a rudimentary condition. The superior spinous processes of these vertebræ are flattened and converted into broad osseous plates, which form a longitudinal series along the centre of the back, and are connected together by sutures resembling those of the human cranium. The ribs are changed into broad flat bones, firmly united by suture to each other and also to the lateral margins of the spinous processes of the vertebræ, so that they all form, as it were, a single broad plate: the heads of the ribs are very feebly developed, and the intervals between them and the bodies of the vertebræ filled up with ligament. The margin of the shield thus formed by the dorsal ribs is further enlarged by a third set of flat bones, apparently representing the sternal ribs of the Crocodile, fixed by suture around the whole circumference of the *carapax*, which they assist in completing.

(1910.) The *plastron*, or *sternum*, is made up of nine pieces, which have been proved by M. Geoffroy St.-Hilaire to be the elements of this portion of the skeleton in the most complete state of development in which they are met with. Of these nine elements, eight are disposed in pairs; but the ninth, which is always placed between the four pieces composing the two anterior pairs, is single, and occupies the mesial line. In birds, we shall afterwards find this element of the sternum performing a very important office.

(1911.) The bones of the shoulder and of the hip, in the Tortoise (fig. 336), are absolutely placed within the thorax, and articulated to the sides of the vertebral column. The precise homology of the scapular apparatus has not been as yet decidedly pointed out; there are, however, three branches, probably representing the *scapula*, the *clavicle*, and the *coracoid* bone: but in the construction of the pelvis, the *ilium*, the *ischium*, and the *pubis* are identified with facility.

(1912.) The muscular movements of Reptiles are ordinarily slow and languid, a circumstance which no doubt depends upon the impurity of their blood, consequent on the imperfect manner in which the circulating fluid is exposed to the influences of respiration. The muscles of these animals are, however, peculiarly tenacious of life, and preserve their irritability and power of contraction for an astonishing length of time after they have even been separated from the body. The muscles of a Turtle will continue to live for days after the creature has been decapitated; and the heart will still contract, when irritated, even many hours after its removal.

(1913.) But perhaps the most interesting phenomenon connected with the muscular system of the Reptilia is the progressive development of entirely different sets of muscles as the metamorphosis goes on by which they are converted from their earliest fish-condition to their mature and perfect state. This series of changes, which doubtless takes place in all the higher Vertebrata, is well exemplified in the tadpole of the Frog or Toad, and the different phases of development are in such creatures easily investigated. At first the tadpole presents the muscular structure of a fish, both in the muscles of the expanded and vertical tail and in those of the branchial apparatus. As growth proceeds, the broad muscles of the abdomen become developed; and ultimately those of the limbs are superadded as those members successively make their appearance, the muscles of the shoulder and pelvic region being first recognizable, and subsequently those of the legs and feet. In the meantime, as the abdominal muscles and those of the extremities become gradually perfected, those peculiar to the fish-state are rapidly removed: the broad tail becomes atrophied and absorbed, diminishing in length nearly at the rate of a line a day; the flaky lateral muscles of the caudal region disappear altogether; and, moreover, the entire muscular apparatus of the branchial and hyoid systems is altered as the character of the respiratory organs becomes changed, in a manner to be explained hereafter, from the aquatic to the aërial condition.

(1914.) As Reptiles, for the most part, must from necessity swallow their prey entire, organs of taste would be scarcely more useful to them than to the fishes described in the last chapter; and we are therefore not at all surprised to find the tongue in almost every family appropriated to a totally different use, and not unfrequently converted into an apparatus of prehension, whereby the food is seized and conveyed into the mouth.

(1915.) In the Batrachoid Amphibia, for instance, we have a remarkable example of this provision. The Frog and the Toad, notwithstanding their slow and clumsy movements, are destined to feed upon insects, and consequently must be provided with some instrument by which such active prey may be caught. The organ provided for this purpose is the tongue, which, by a slight modification in its structure, becomes changed into a prehensile forceps admirably adapted to such an office. The tongue of the Frog, instead of presenting the usual arrangement, is found to be fixed to the symphysis of the lower jaw, and folded back upon itself, so that its point, which is free and bifid, is lodged in the throat. Thus provided, the Frog is enabled to seize its victim with the greatest ease. No sooner does a fly approach sufficiently near, than this living forceps is rapidly everted; and the insect, being seized by its furcate extremity, is as speedily brought between the jaws of its destroyer. The teeth of the Batrachia very much resemble those of the generality of fishes, being simple points soldered to the surface of the jaws, but not implanted in sockets—sufficient to give a secure hold of their food, but quite unadapted to mastication.

(1916.) The Chameleon is another curious example of a reptile obliged to employ its tongue in securing insect prey. The Chameleon is arboreal in its habits: its feet, cleft as it were into two portions, firmly grasp the boughs upon which it climbs; while its well-known power of changing the colour of its skin, so as to imitate that of the branches around it, efficiently conceals it from observation. The tongue of this creature, when extended, is as long as its whole body, and is terminated by a club-shaped extremity smeared over with a viscid secretion: when an insect comes within a distance of five or six inches from the Chameleon, the end of this tongue is first slowly protruded to the distance of about an inch, and then, with the rapidity of lightning, launched out with unerring aim; the fly, glued to its extremity, is with equal velocity conveyed into the mouth.

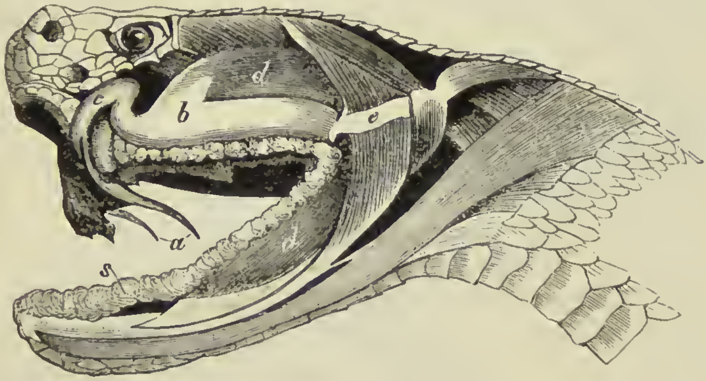
(1917.) The jaws of the Chelonian Reptiles are not armed with teeth, but cased in horny coverings, so as to resemble the beak of a bird, with which they crop the vegetable aliment upon which they generally subsist.

(1918.) Serpents, as regards their means of destroying prey, may be divided into two great groups—the first including those which are not venomous, the second embracing such as are armed with poison-teeth.

(1919.) In the non-venomous Serpents, as for example in the *Boa Constrictor*, the upper jaws and the palate-bones are all lined with sharp teeth, so that there are four rows of dental organs, two placed along the margins of the maxilla, and two projecting from the roof of the mouth: all these teeth are simple, very sharp, and point backwards. Each division of the lower jaw is likewise armed with a single row, which are also directed towards the back of the mouth. It must be evident, from a mere inspection of these teeth, that they can be of little use in holding, much less in destroying, such strong and large animals as the Boa devours; and upon a little consideration we shall find that they are intended for a very different office. These serpents kill their victims by coiling their lengthy bodies around the chest, and then by strong muscular contraction they compress the thorax of their prey so firmly, that, its movements being completely prevented, respiration is put a stop to, and the animal so seized speedily perishes from suffocation. But, having succeeded in extinguishing life, the most difficult task still remains to be accomplished: how is the serpent, utterly destitute as it is of all external limbs, to force down its throat the carcase of a creature many times thicker than its own body? The mode adopted is as follows:—once more winding itself around the slain animal, it commences at the head, which by main force it thrusts into its mouth; the elastic ligament at the symphysis of its lower jaw gives way, and the branches of the inferior maxilla become widely separated, so that the mouth is stretched enormously as the food is thus forced into it. Deglutition is here a very lengthy and laborious process; and were there not some special contrivance to guard against such an accident, no sooner were the efforts of the snake relaxed in the slightest degree than the muscles of the throat and jaws, being in a state of extreme tension, would force out of the mouth what had already been partially swallowed. To provide against this, the teeth are in this case converted into a sort of valve: pointing backwards, as they all do, they permit the bulky food to pass into the fauces; but at the same time their sharp points, being directed towards the throat, efficiently prevent it from being pushed back again in the opposite direction*.

(1920.) In the venomous serpents, those teeth which are fixed to the margin of the superior maxillary bone of the innoxious genera are generally deficient; and instead of them there is found an apparatus of poison-fangs, constituting perhaps the most terrible weapons of attack met with in the animal creation. The poison-teeth (fig. 337, *a*) are two in number, one fixed to each superior maxillary bone: when not in use, they are laid flat upon the roof of the mouth, and covered by a kind of sheath formed by the mucous membrane of the palate; but when the animal is irritated, or about to strike its prey, they are plucked up from their concealment by muscles inserted into the upper maxillary bone, and stand out like two long lancets attached to the upper jaw. Each fang is traversed by a canal—not, as it is generally described, excavated in the substance of the tooth, but formed by bending, as it were, the tooth upon itself, so as to enclose a narrow channel through which the poison flows. The canal so formed opens towards the base of the tooth by a large triangular orifice; but at the opposite extremity it terminates near the point of the fang by a narrow longitudinal fissure. The gland wherein the poison is elaborated occupies the greater part of the temporal fossa, and is enclosed in a white and tendinous capsule (fig. 337, *b*); the substance of the organ is spongy, and composed of cells communicating with its excretory duct (*c*), by which the venom is conveyed to the opening at the base of the fang †. The poison-gland is covered by a strong

Fig. 337.



Structure of the poison-teeth of the Rattlesnake.

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[*] In the collection of Professor Bell there is a small snake which, having by mishap attempted to swallow a mouse of too large size, and being quite unable, in consequence of the mechanism referred to, to disgorge it, was found dead, and the skin and muscles of its neck absolutely rent from excessive stretching.

[†] Mémoire sur les caractères tirés de l'Anatomie pour distinguer les Serpens venimeux des Serpens non-venimeux; par M. Duvernoy (Ann. des Sc. Nat. xxvi.).

process of the temporal muscle (*d*), which is attached to a thin aponeurotic line (*e*). The greater portion of the fibres of this muscle take their origin from the capsule of the secreting apparatus, which they partially envelope; and then winding round all the posterior part of the gland, and passing behind the commissure of the lips, the lower part of the muscle is firmly implanted into the lower jaw very far anterior to the angle of the mouth. The process of the temporal muscle which thus surrounds the gland is very thick and strong, so that it is easy to imagine with what force the poison will by this mechanism be injected into the wounds inflicted by the fangs, seeing that the same muscles which close the jaw at the same time compress the bag of venom with proportionate energy.

(1921.) Behind the large poison-fang in use, the capsule that encloses it generally contains the germs of several others, ready to supply its place should the former be broken off; and in the event of such an accident, one of these supplementary teeth soon becomes consolidated with the superior maxilla, and adapted in all respects to take upon itself the terrible office of its predecessor.

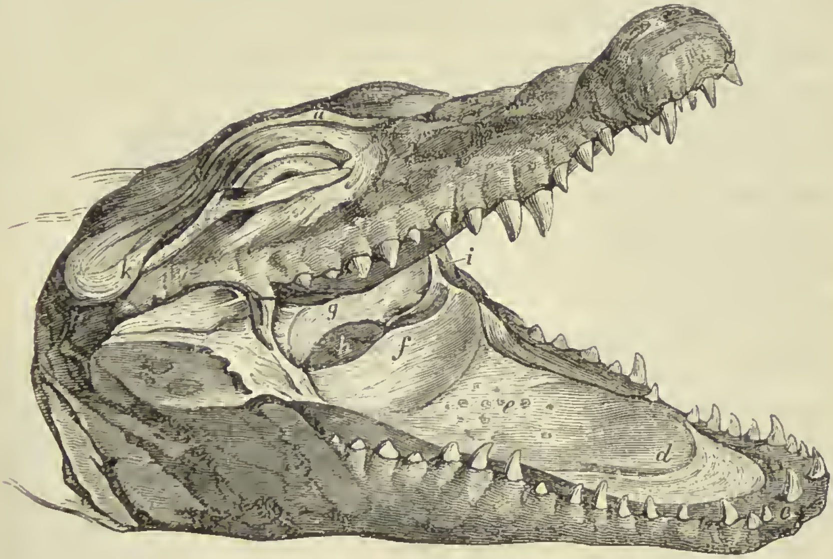
(1922.) Dreadful as are the means of offence thus conferred upon the poisonous serpents, it is impossible to avoid noticing in this place that admirable provision of Nature which, in one genus at least, serves to give timely warning of the vicinity of such dangerous assailants. We need merely mention the rattle of the Rattlesnakes (*Crotalus*)—an organ the intention of which is so obvious that the most obtuse cannot contemplate it without at once appreciating the beauty of the contrivance. This singular rattle is formed of numerous horny rings, that are in fact merely modifications of the general scaly covering of the reptile, so loosely articulated together that the slightest movement of their formidable possessor is betrayed by the startling noise produced by the collision of the different pieces composing the organ: even when at rest, the creature announces by rapid vibrations of the tail the place of its concealment, apparently to caution the inadvertent intruder against too near an approach.

(1923.) In the grand police of Nature, the scavengers are by no means the least important agents. In hot climates especially, where putrefaction advances with so much rapidity, were there not efficient and active officers continually employed in speedily removing all dead carcases and carrion, the air would be perpetually contaminated with pestilential effluvia, and entire regions rendered uninhabitable by the accumulation of putrefying flesh. Perhaps, however, no localities could be pointed out more obnoxious to such a frightful cause of pestilence than tho banks of the tropical rivers—those gigantic streams which, pouring their waters from realm to realm, daily roll down towards the sea the bloated remains of thousands of creatures which taint the atmosphere by their decomposition.

(1924.) Such are precisely the situations inhabited by Crocodiles and Alligators, the largest of the Saurian reptiles now in existence, animals in every way designed by Nature to feed upon putrefying materials: their tongue (fig. 338, *d*) scarcely projects from the lining membrane of the mouth, and its surface (*e*) is studded with large glands; the whole interior of the mouth is in fact, from its construction, little adapted to gustation.

(1925.) The Crocodile, nevertheless, likewise kills living prey, which, from the structure of its teeth, it is obliged to effect by dragging its victim into the water and there drowning it. This mode of proceeding, however, simple as it might appear, involves many difficulties. As the reptile has no other instruments of prehension besides its mouth, and is obliged to hold its struggling prey submersed by the strength of its formidable jaws, it is manifest that, without some special contrivance, the water rushing into the throat of the Crocodile would prevent it from breathing quite as effectually as the animal it endeavours to drown; it might therefore become a question which of the two would survive immersion longest. The mechanism employed under these circumstances to give the Crocodile the advantage over its prey is very complete: a broad cartilaginous plate (fig. 338, *f*) stands vertically from the os hyoides, and projects upwards into the back part of the mouth; a similar valve (*g*) hangs down from the back of the palate, so that the two together form a kind of flood-gate, which, when the mouth is widely opened, effects a complete partition between the cavity of the mouth and the fauces, where the aperture of the larynx (*h*) is situated. The nostrils, moreover, are placed quite at the extremity of the snout,

Fig. 338.



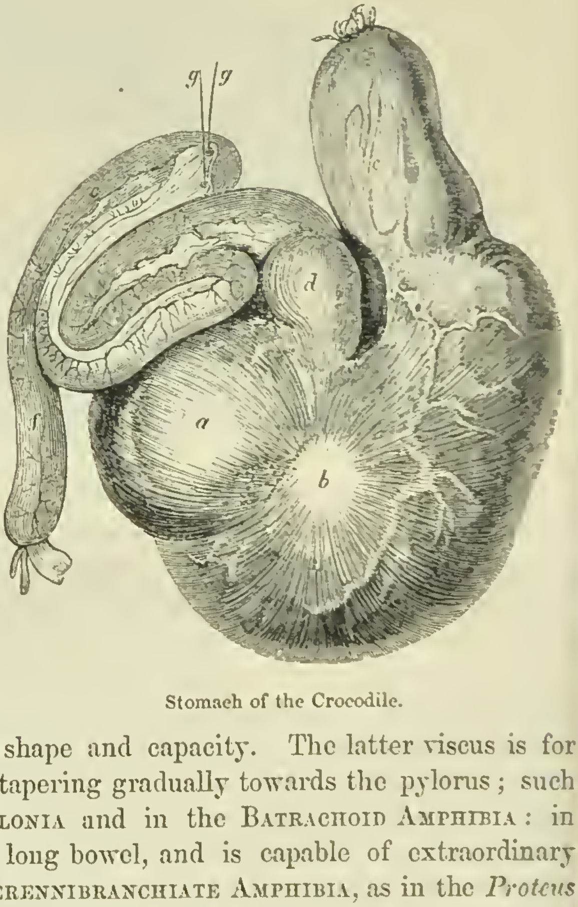
Mouth of the Crocodile.

and the nasal passages leading from them are prolonged through the whole length of the upper jaw until they communicate with the fauces, behind the velum of the palate (*g*). Such being the arrangement, it is immediately obvious that, when the communication between the mouth and the fauces is cut off by means of the two valves (*g*, *f*), the Crocodile, by merely keeping the tip of its snout above the water, breathes with the utmost facility, and it is thus enabled to keep its prey submerged for any length of time that may be requisite to extinguish life.

(1926.) The teeth of the Crocodile and of the higher Saurians are not merely consolidated with the bones of the skull to which they are appended, but are implanted in sockets formed in the bones composing the upper and lower jaws. Each tooth is a simple hollow cone, and encloses a vascular pulp, from the surface of which the bony matter of the tooth was formed. When a tooth becomes old and worn, a second is secreted by the same pulp within the cavity of the first, and the original one is shed, so that a succession of teeth thus make their appearance.

(1927.) The alimentary canal of Reptiles offers little that requires special description. The œsophagus (fig. 343, *f f*) is generally extremely capacious, and the stomach of very variable shape and capacity. The latter viscus is for the most part pyriform, tapering gradually towards the pylorus; such is the case in the Chelonia and in the Batrachoid Amphibia: in Serpents it resembles a long bowel, and is capable of extraordinary dilatation; and in the Perennibranchiate Amphibia, as in the *Proteus* (fig. 340, *i*) and the *Menopoma* (fig. 343, *g*), it looks like a mere dilatation of the intestine.

Fig. 339.



Stomach of the Crocodile.

(1928.) The stomach of the Crocodile is remarkable as affording another among the innumerable instances that might be adduced of that gradual transition everywhere observable as we pass from one class of animals to that which next succeeds it in the series of creation. The

Crocodile is the connecting link between Reptiles and Birds, and in almost every part of its body it presents a type of structure almost intermediate between the two.

(1929.) The stomach of this creature (fig. 339) might, in fact, be almost mistaken for the gizzard of a rapacious bird. The œsophagus (*c*) terminates in a globular receptacle, the walls of which are very muscular; and the muscular fibres (*a*) radiate from a central tendon (*b*) precisely in the same manner as those of a bird. The pyloric orifice is closely approximated to the termination of the œsophagus, and the commencement of the duodenum dilated into a round cavity (*d*),—an arrangement which, as we shall see in the next chapter, exactly resembles that met with in the feathered tribes.

(1930.) In the neighbourhood of the pylorus, the walls of the stomach in all the Reptilia become perceptibly thickened; the intestine is generally short, and usually divided into two portions, representing the small intestines and the colon, the division between the two being marked by a prominent valve analogous in function and position to the ilio-colic valve in the human subject; and sometimes, moreover, as for instance in the *Iguana*, there is a distinct cæcum developed at the commencement of the large intestine.

(1931.) The auxiliary secretions subservient to digestion in the class before us are the *salivary*, the *hepatic*, and the *pancreatic*.

(1932.) The salivary glands are of very peculiar construction *. In the Chelonian, the Saurian, and the Batrachian orders, the substance of the tongue seems to be principally made up of a thick glandular mass, formed by a multitude of little tubes united at their bases; but, becoming separate towards the surface of the tongue, they give the whole organ a papillose or velvety appearance. This glandular apparatus rests immediately on the muscles of the tongue, and upon its sides a multitude of pores are visible, through which the salivary secretion exudes.

(1933.) In the Ophidian Reptiles, from the manner in which they swallow their prey, the bulk of the tongue is necessarily reduced to the utmost extent; the whole organ seems converted into a slender bifid instrument of touch, and is covered with a delicate membrane. Instead of the salivary apparatus described in the last paragraph, two glandular organs (fig. 337, *s s*), placed immediately beneath the skin of the gums, surround the margins both of the upper and lower jaws; and from these an abundant salivary secretion is poured into the mouth, through orifices situated externally to the bases of the teeth.

(1934.) The liver of Reptiles (fig. 340, *h*) requires no particular description: its secretion, as well as that of the pancreas (fig. 340, *o*), is poured into the intestine in the usual manner, at a little distance from the pylorus.

(1935.) The *spleen* and system of the *vena portæ* are disposed in the same manner as in other Vertebrata. The spleen (fig. 340, *l*) is generally more or less closely connected with the stomach; and the large vein derived from it, being joined by those proceeding from the other viscera of the abdomen, forms the trunk of the portal vein (*m*), which soon divides again into numerous branches that ramify in the substance of the liver.

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* Cuvier, Leçons d'Anatomie Comparée, iii. p. 223.

(1936.) The lymphatic and lacteal systems are very important parts of the economy of these creatures; and, from the large size of the absorbent vessels, their disposition is more easily traced in the class before us than in any other. The principal trunks surround the aorta and other large blood-vessels, and communicate very extensively with the veins in different parts of the body. From the imperfect condition of the valves in their interior, the lacteals of many tribes may be readily injected from trunk to branch, and when thus filled with mercury, they are found to spread out between the coats of the intestines like a dense network of silver.

(1937.) But the most remarkable circumstance connected with the absorbents of this class of animals is the discovery, made by Professor Müller of Berlin*, of a system of lymphatic hearts destined to propel the products of absorption from the chief lymphatic trunks into the veins. In the Frog, four of these pulsating cavities are easily displayed by simply raising the skin covering the regions of the body where they are situated. The posterior pair of hearts are appendages to the lymphatic trunks which convey the absorbed fluids derived from the hinder extremities into the ischiadic veins; they are situated on each side midway between the extremity of the long bone which represents the *os coccygis* and the hip-joint, and are placed immediately beneath the integument. They each consist of a single cellular cavity, and pulsate regularly; but their pulsations are quite independent of those of the heart, neither are the contractions of the two lymph-hearts synchronous with each other.

(1938.) Another pair of these contractile cavities is situated beneath the posterior margin of the scapula, close to the transverse process of the third vertebra: this pair forces the contents of the lymphatics of the anterior portions of the body into the jugular veins.

(1939.) Fishes respire water by means of gills. Reptiles, breathing a lighter medium, are provided with lungs—membranous bags, into which the external element is freely admitted, and again expelled in a vitiated condition, its oxygen having been employed in renovating the blood, which circulates in an exquisite network of delicate vessels that ramify in rich profusion over the walls of the pulmonary chamber.

(1940.) This important difference between Fishes and Reptiles as relates to their mode of respiration would seem, at first sight, to draw such a distinct line of demarcation between these two great classes of Vertebrata that it would be impossible for the most superficial zoologist to confound one with the other, or to be for a single moment at a loss in attempting to assign to any creature belonging to either of these divisions of the animal world its proper position; indeed, to mistake an air-breathing reptile for a fish properly so called, would appear to be an error which the most ignorant naturalist could hardly be in danger of committing.

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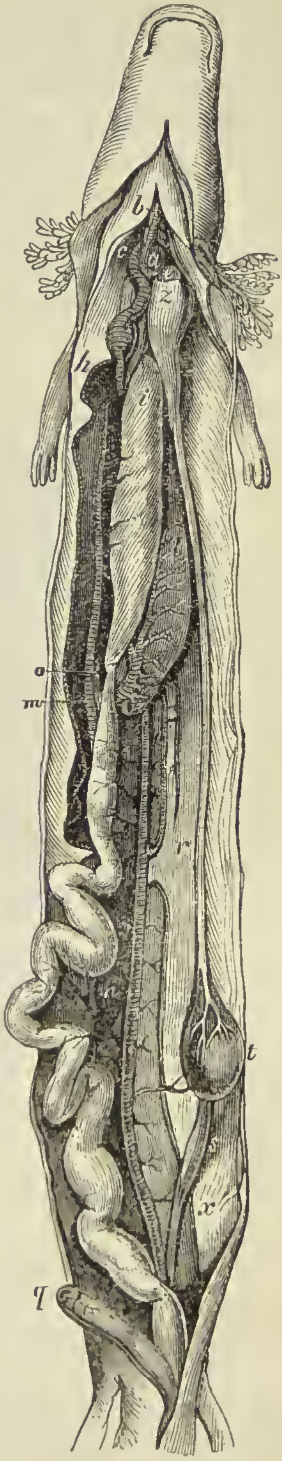
* *Vide* Berlin Annals for 1832; and also Panizza, sopra il Sistema Linfatico dei Rettili. fol. Pav. 1833.

(1941.) We have, however, again and again had opportunities of observing how nearly animals of neighbouring classes approximate each other, not only in their outward form, but in their anatomical construction, and in considering this portion of our subject we shall have another most striking illustration of this great law in zoology.

(1942.) The perfect and typical Reptile, as the Lizard, the Tortoise, and the Serpent, breathes air, and air only, and is therefore only provided with lungs adapted to this kind of respiration; but the Perennibranchiate Amphibia, possessing both lungs and gills, participate to a greater or less degree in the characters of Fishes; so that in some, as, for example, in the *Lepidosiren* (fig. 328), so near is the approximation, that it becomes almost impracticable for the most accomplished anatomist precisely to determine whether the animal ought rather to be called a reptile or a fish; and lastly, in the Batrachian Amphibia, as we have already seen, we have the same animal gradually changed from a fish into a complete and perfect reptile.

(1943.) In considering the apparatus provided for circulation and respiration in the animals comprised in the class before us, we shall therefore first describe the organization of these viscera in Reptiles furnished with lungs only; secondly, of those having

Fig. 340.

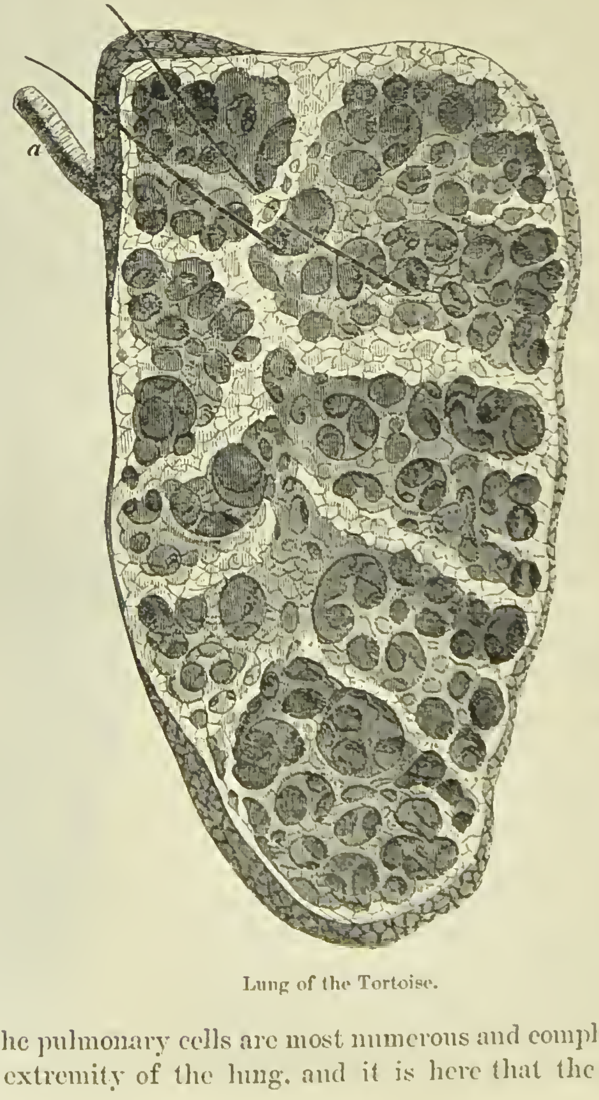


Anatomy of *Proteus anguinus.*

permanent gills as well as lungs; and thirdly, the metamorphoses that take place in the construction of the breathing organs during the development of the lungs, and the obliteration of the branchiæ in those forms in which the branchiæ are not persistent.

(1944.) The lungs of Reptiles are two capacious membranous sacs occupying a considerable portion of the visceral cavity, which, as there is no diaphragm as yet developed, cannot properly be divided into thorax and abdomen, as it is in Mammalia. From the internal surface of the walls of each lung membranous septa project inwards, so as partially to divide the interior of the organ into numerous polygonal cells, which are themselves subdivided into smaller compartments in a similar manner. This structure is well seen in the lung of the Tortoise (fig. 341).

Fig. 341.



Lung of the Tortoise.

(1945.) The pulmonary cells are most numerous and complete towards the anterior extremity of the lung, and it is here that the pulmonary vessels principally ramify: towards the hinder part of the viscus the cells become larger, and the breathing-surface proportionately less extensive, until in some cases, as in Serpents, the cells being quite obliterated, the lung terminates posteriorly in a simple membranous bladder.

(1946.) The air is brought into the lungs through a long trachea, composed, as in other Vertebrata, of a series of cartilaginous rings; but there is this peculiarity in the construction of the Reptile lung—the trachea never divides into bronchial ramifications, but terminates abruptly by one or more orifices which open at once into the general pulmonary cavity.

(1947.) It must be evident, from the whole construction of a lung of this description, that, owing to the comparatively limited surface that it presents internally, it is far less adapted efficiently to expose the circulating fluid to the influence of the atmosphere than the more complex apparatus of Birds and Mammalia: the respiration of Reptiles is consequently proportionately imperfect; and hence that coldness of their blood and feebleness of muscular movement which are so characteristic of the entire class.

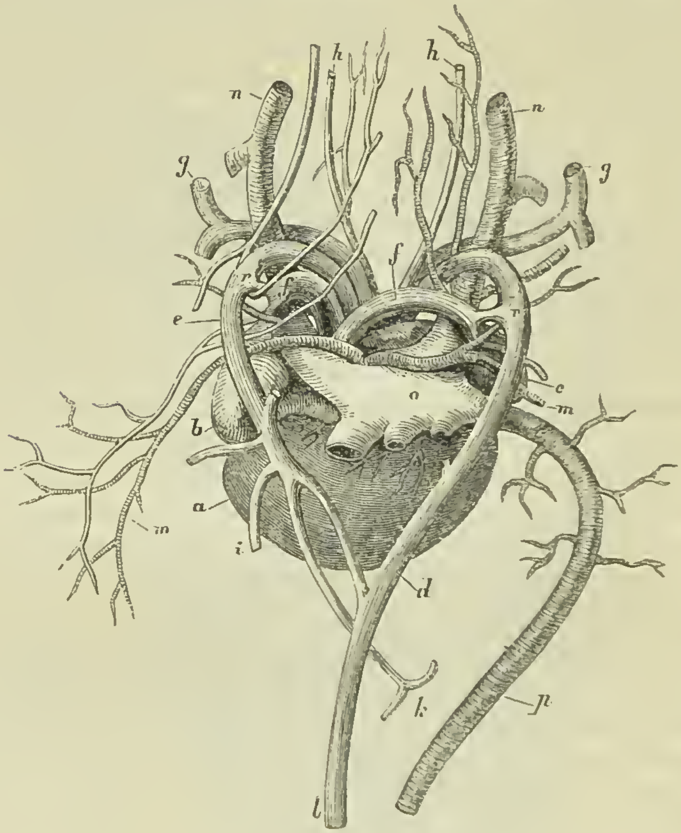
(1948.) The air required for purifying the blood is, of course, continually changed, being alternately taken into the lungs, and again expelled in a deteriorated condition, by a mechanism which will be found to vary in different reptiles in accordance with the peculiarities of their organization. No Reptile possesses a diaphragm; and being destitute of this important muscle, the movements whereby inspiration and expiration are accomplished are, in such genera as are furnished with moveable ribs, entirely dependent upon the mobility of the framework of the chest—the dilatations and contractions of the thorax, consequent upon the alternate elevation and depression of the ribs, being sufficient to ensure the inhalation and expulsion of air: such is the case in the Serpent and the Lizard.

(1949.) In the Amphibia, however, there are not even ribs developed, or, if they exist at all, they are such mere rudiments as to be quite useless as instruments of respiration; and on the other hand, in the Chelonian Reptiles, the large and expanded bones of the thorax are so consolidated together, and so immoveably fixed to the broad and osseous sternum, that respiration in the ordinary manner would be altogether impracticable. Under these circumstances, as a compensation for the want of mobility in the chest, the *os hyoides* and the muscles of the throat are converted into a kind of bellows, by which the air is forced mechanically into the lungs, and they are thus distended at pleasure.

(1950.) Any one who watches a Frog or a Tortoise with a little attention will at once understand the mechanism by which this is effected. The mouth is kept closely shut; and the nostrils, which open immediately into its cavity, are each provided with a muscular valve, so disposed as freely to permit the entrance of air into the mouth, but also effectually preventing its return by the same channel. By this arrangement the descent of the hyoid apparatus fills the mouth with air; and the subsequent contraction of the broad muscles of the throat, the nostrils and the pharynx being of course both closed, forces the air into the opening of the larynx, and distends the lungs, from which it is again expelled by the pressure of the abdominal muscles.

(1951.) The structure of the heart and the course of the circulation in Reptiles afford interesting subjects for investigation. The heart consists of three cavities, namely, a strong and muscular ventricle (fig. 342, *a*), and two membranous and very capacious auricles, both of which communicate by valvular openings with the ventricular cavity. The right auricle (*b*) receives the venous blood from all parts of the body through the venæ cavæ (*n*, *o*, *p*), the terminations of which are guarded by strong valves; the left auricle (*c*) is appropriated exclusively to the lungs, from which it receives arterial blood through the pulmonary veins (*m m*). It is obvious, therefore, that the ventricle receives two kinds of blood from the two auricles—venous blood from the systemic auricle, and arterial blood from the pulmonic auricle; and as the interior

Fig. 342.



Heart of the Tortoise.

of the ventricular cavity is crossed by innumerable *columnæ carneæ*, giving it almost a spongoid appearance, the vitiated and purified blood derived from these two sources are more or less completely mixed together, and blood only partially arterialized is distributed to the system.

(1952.) Two sets of vessels take their origin from the single ventricle, viz. the pulmonary and aortic. The *pulmonary artery* soon divides into two trunks (*f f*), one destined to each lung; so that a part of the impure blood expelled from the ventricle is at once driven to the organs of respiration to be further oxygenized. The *aorta*, immediately after its origin, likewise separates into two trunks (*d*, *e*), the right and the left, which, winding backwards, ultimately join to form one great vessel (*l*), from which the arteries of the viscera (*i*, *k*) and those destined to the posterior parts of the body are given off. From the commencement of the right aortic trunk a very large vessel is furnished, which bifurcates to form two *arteriæ innominatæ* (*g g*), from which the carotid and subclavian arteries take their origin.

(1953.) Although the above description refers more immediately to the construction of the heart of the Tortoise, in all essential particulars it is equally applicable to all reptiles of the Saurian, Chelonian, and Ophidian orders; and when we thus see that, in addition to the comparatively imperfect condition of their lungs, the blood which circulates through the body is in these creatures a mixed and semivenous fluid, we need not be surprised at the contrast which they offer when compared with the hot-blooded and vigorous animals to be described in the subsequent chapters of this work.

(1954.) Cuvier committed a serious error in describing the Batrachian reptiles as having a heart composed of but two cavities; our illustrious countryman John Hunter had already ascertained that, in Frogs, Toads, and Salamanders, the heart possessed a pulmonary as well as a systemic auricle; and his observations have since been abundantly confirmed by Dr. Davy, Dr. Martin St.-Ange, and Professor Owen. The pulmonic auricle in these creatures, indeed, is comparatively of small size; but it exists as a perfectly distinct chamber, and receives the blood from the lungs preparatory to its admission into the common ventricle.

(1955.) With regard to the use of the additional auricle in the Reptilia, Professor Owen has well remarked* that, from the impediments which frequently occur to a free and regular circulation of blood in these cold-blooded and slow-breathing creatures, the venous side of the heart is subject to great distension; hence the large size of the auricles, and of the sinus which receives the systemic veins, and also the perfect development of the valves intervening between the venæ cavæ and the auricle, of which the Eustachian valve of the *Mammiferous* heart still presents a rudiment. Had the pulmonary veins terminated along with the systemic in the same cavity, their orifices would have been subjected to the pressure of the accumulated contents of that cavity, and there would have been a disproportionate obstacle to the passage of the aërated blood into the ventricle. This is obviated by providing the pulmonary veins with a distinct receptacle, which is equally ready with the right auricle to render its contents into the ventricle during the diastole of that cavity.

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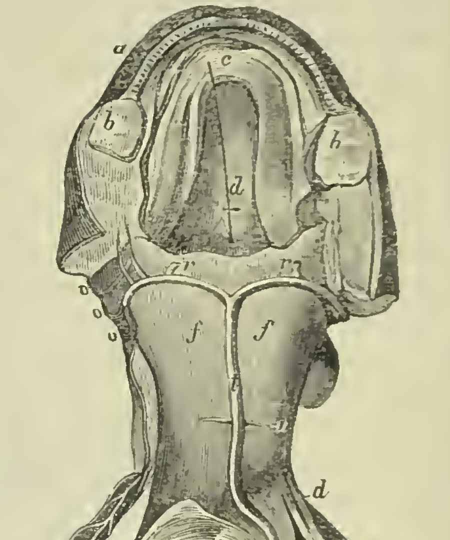
* Transactions of the Zoological Society of London, vol. i. p. 217.

Fig. 343.



Circulation in *Menopoma.*

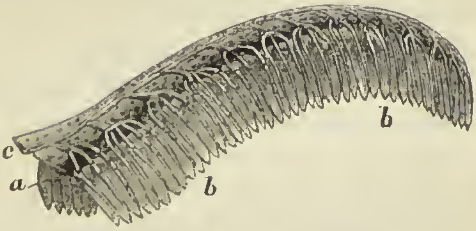
(1956.) Passing from the consideration of the more perfect Reptile circulation as it exists in those genera which in their adult condition possess lungs only, to those which may properly be called Amphibious, and are provided with both lungs and gills throughout the whole period of their lives, we must still pause to notice one or two intermediate forms, which, notwithstanding that they lose their branchiæ at an early stage of their growth, are evidently closely related to the Perennibranchiata, as may be gathered from the arrangement which their blood-vessels permanently exhibit. Such is the *Menopoma*, or Great South American Salamander, an animal met with in the rivers and lakes of the South American continent. In the annexed figure, taken from the Catalogue of the Hunterian Collection, the principal vessels of this creature are delineated as seen from the dorsal aspect. The lower jaw (fig. 343, *a*) has been removed from the head, so that in the drawing are exposed the cut edge of the masseter muscle (*b*), the tongue (*c*), and the opening of the larynx, into which a bristle (*d*) has been introduced, one end of which is seen passing into the cavity of the right lung: the bag of the pharynx (*f f*) has been left entire: and upon this the main vascular trunks are supported. From the heart, situated upon the opposite side of the œsophagus, is given off a large vessel representing the *bulbus arteriosus* of fishes, which terminates by dividing into four branchial arteries; but as in the adult Menopoma there are no branchiæ, these vessels (*o o o*) wind round each side of the neck, and again unite into two trunks (*r r*) which by their union form the aorta (*t t*). It will easily be perceived that this arrangement is precisely that met with in fishes; *only that, as there are here no gills intervening between the terminations of the branchial arteries and the commencements of the branchial veins, these vessels are immediately continuous with each other.* Moreover, from the lowest branchial arch (*o*) a *pulmonary artery* is given off, which ramifies over the surface of the as yet rudimentary lung (*e*), and thus gives rise to a distinct pulmonary circulation.

(1957.) Having carefully considered the disposition of the vessels in the *Menopoma* above described, the reader will be able to appreciate the arrangement of the vascular system in those Amphibia which, being provided with both gills and lungs through the whole of their lives, literally combine the blood-vessels of a fish with those of an air-breathing reptile.

(1958.) In the Perennibranchiata, as, for example, in the *Proteus*, instead of the *bulbus arteriosus* being immediately continuous with the aorta (as it is in the *Menopoma*) through the interposition of the vessels *o o o* (fig. 343), the blood derived from the heart is obliged to pass more or less completely through gills appended to the sides of the neck before it arrives in the vessels (*r r*) which may be said to represent the branchial veins of fishes.

(1959.) The branchiæ are either vascular tufts or pectiniform organs (fig. 344, *b b*), essentially analogous in structure to those of a fish. The blood, however, which is propelled from the heart is not here entirely venous, but consists of a mixed fluid, partially derived from the systemic and partially from the pulmonary auricle, the two having, of course, been mingled together in the common ventricle of the tripartite heart. The contraction of the heart forces the blood into the *bulbus arteriosus*, from which it is in great part driven into the branchiæ: arrived there, it passes along the great branchial artery (fig. 344, *a*), is made to circulate over the branchial fringes (*b*), and being again collected into the branchial vein (*c*), in a purified condition, it is poured into those large trunks, the representatives of the vessels *r r* (fig. 343), which form the aorta.

Fig. 344.



Branchia of *Proteus anguinus*.

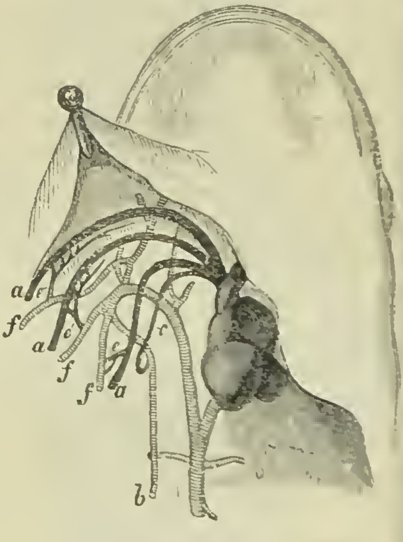
(1960.) But, besides the branchial circulation, these creatures likewise possess lungs (fig. 340, *z, t*), and a pulmonary circulation of greater or less importance in different genera. Nevertheless the pulmonary artery is merely a small twig given off from the aortic system of vessels, through which semi-arterialized blood passes to the lungs, to be returned in a still purer condition to the left auricle of the heart.

(1961.) If the student has fully comprehended the permanent condition of the blood-vessels as it exists in the perfect Reptile and in the Perennibranchiate Amphibian, he will have little difficulty in understanding the changes which occur in the distribution of the vascular system during the metamorphosis of the CADUCIBRANCHIATA.

(1962.) In the Salamander, when the lungs begin to be developed and are coexistent with the branchial apparatus, the arrangement of the circulating system is precisely similar to that described as being permanent in the Perennibranchiata; as may be seen by a reference to the appended diagram, which would equally illustrate the distribution of the blood-vessels in both cases.

(1963.) In this early stage of the tadpole's life, the contraction of the heart and bulbus arteriosus drives the greater part of the blood through the branchial veins (fig. 345, *a a a*) to the gills, from which it is returned in a purified condition by the branchial veins (*f f f*), which, by their union, at length form the *aorta*, as in fishes. At this period the pulmonary artery (*b*), which is very small, in correspondence with the as yet rudimentary condition of the lungs, is merely a branch derived from the aortic system, and reinforced by a vessel (*c*) given off from the bulbus arteriosus. The greater proportion of the blood therefore evidently goes to the branchiæ, and a very small part to the lungs.

Fig. 345.



Course of the circulation in *Proteus anguinus*. (After Rusconi.)

(1964.) The reader must, however, here remark that there are small anastomosing vessels (fig. 345, *c c c*), uniting the branchial arteries with the trunks of the branchial veins, and that these are situated just at the roots of the gills, since these vessels become of the utmost importance during the subsequent stages of the metamorphosis.

(1965.) The branchiæ gradually become diminished in size, and a smaller quantity of blood passes through them; and as this goes on, the vessels (*a a a*, *f f f*) shrink in the same proportion. Meanwhile the lungs are progressively more and more developed, and the pulmonary artery (*b*) expands in an equal ratio. As the blood forces its way with more difficulty through the branchiæ, the anastomosing vessels (*c c c*) dilate, and a freer supply of blood is poured into the pulmonary system; until at last, when the lungs are fully formed, and the branchial arteries (*a a a*) and veins (*f f f*) quite obliterated, all the blood necessarily passes immediately through the anastomotic trunks (*e e e*), which of course then represent the vessels (*o o o*) of the *Menopoma* (fig. 343); and the mode of respiration is thus completely converted from that of a Fish into that of a true Reptile.

(1966.) But during the progress of these changes in the disposition of the vascular system, others not less wonderful take place in the form and uses of the entire hyoid apparatus, and in those muscles of the throat which are connected with the function of respiration.

(1967.) The hyoid apparatus of the tadpole is, in fact, a very complicated structure*, and, like that of the fish, supports the branchiæ, and facilitates the entrance and expulsion of the water; moreover, by opening or closing at pleasure the communication which exists through the branchial apertures between the mouth and the exterior of the body, it thus allows air to be taken into the lungs at pleasure.

(1968.) The *os hyoides* of the tadpole, at an early period of its development, supports four branchial arches (fig. 346, A, 1, 2, 3, 4), which bound three branchial fissures, through which, as in a fish, the water escapes from the mouth. The branchial arches 2 and 3 are studded on each side with cartilaginous points, and the arches 1 and 4 have similar points on one side only; so that when the arches are approximated, as they can be by an elaborate temporary set of muscles provided for the purpose, the cartilaginous teeth lock into each other so accurately that the branchial fissures are completely and firmly closed—a provision which is evidently indispensable in order to allow the tadpole to fill its lungs with air.

(1969.) The above is the condition of the branchial portion of the hyoid apparatus before the metamorphosis of the tadpole has made much progress; and from this time a series of changes begins of a most curious and interesting description.

(1970.) When the metamorphosis has commenced, the os hyoides and branchial arches assume the appearance represented at fig. 346, B. The pieces 8 and 9 are no longer both cartilaginous, the latter having become entirely ossified. The branchial arch 1 is likewise converted into bone; and its upper surface, being considerably enlarged, is now connected with both the pieces marked 10 and 11. The three cartilaginous pieces 5, 6, 7, in fig. 346, A, are consolidated into one, while the branchial arches 2, 3, 4 become much reduced in size, the branchiæ approach each other, and the cartilaginous points with which they are provided adhere together, so that from hour to hour, so to speak, the mass (2, 3, 4) composed of the three united branchial arches becomes insensibly obliterated, and in a very few days is entirely absorbed.

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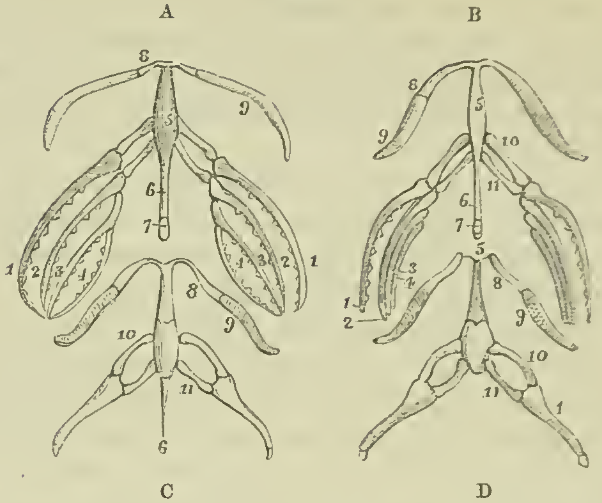
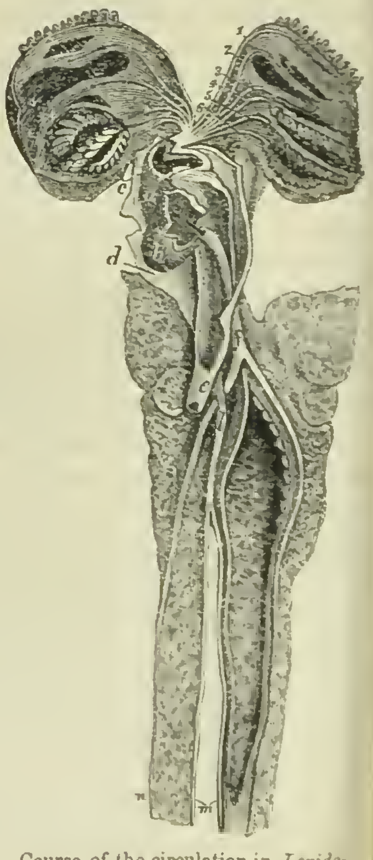
* Recherches anatomiques et physiologiques sur les organes transitoires et la métamorphose des Batraciens, par J. G. Martin St.-Ange (Annales des Sciences Naturelles, xxiv.).

Fig. 346.



Metamorphoses of the os hyoides in the Tadpole. (After Dr. St.-Ange.)

Fig. 347.



Course of the circulation in *Lepidosiren*. (After Owen.)

While this absorption is going on, the branchial arch (1) assumes greater consistency, its inferior extremity becomes directed outwards, and it loses the little cartilaginous teeth previously appended to it; the os hyoides thus assumes the simple form represented in fig. 346, c. Lastly, the cartilage 6 disappears, and the complex branchial apparatus of the tadpole becomes converted into the permanent and comparatively simple os hyoides of the Salamander, depicted in fig. 346, d.

(1971.) The branchial arches 2, 3, 4, Dr. St.-Ange remarks, are absorbed in proportion as the circulation becomes modified, their atrophy depending upon the change which takes place in the course of the blood, owing to the dilatation of the anastomotic vessels (fig. 345, *e e e*) and the enlargement of the pulmonary arteries (*b*). It is, therefore, owing to a kind of revulsion produced by the afflux of the blood towards the pulmonary organ instead of towards the branchiæ, that the atrophy of the branchial capillaries, and subsequently of the whole branchial apparatus, is produced.

(1972.) We must in the last place, before leaving the consideration of the circulating system of the Reptilia, describe that of the *Lepidosiren*, a creature so exactly intermediate between the two classes, that it is really difficult to determine whether it ought most properly to be called a fish provided with lungs, or a reptile with the circulatory organs of a fish.

(1973.) The heart resembles that of a fish, and consists of a single auricle (fig. 347, *a*), a ventricle (*b*), and bulbus arteriosus (*c*). The vena cava (*e*), bringing the vitiated blood from the system, terminates at once in the auricle, which is represented in the figure as laid open; but the pulmonary vein (*f*), whereby the aërated blood is brought from the lungs (*m m*), passes along as far as the auriculo-ventricular opening, where *it empties its contents into the ventricle by a distinct orifice, protected by a cartilaginous valvular tubercle.*

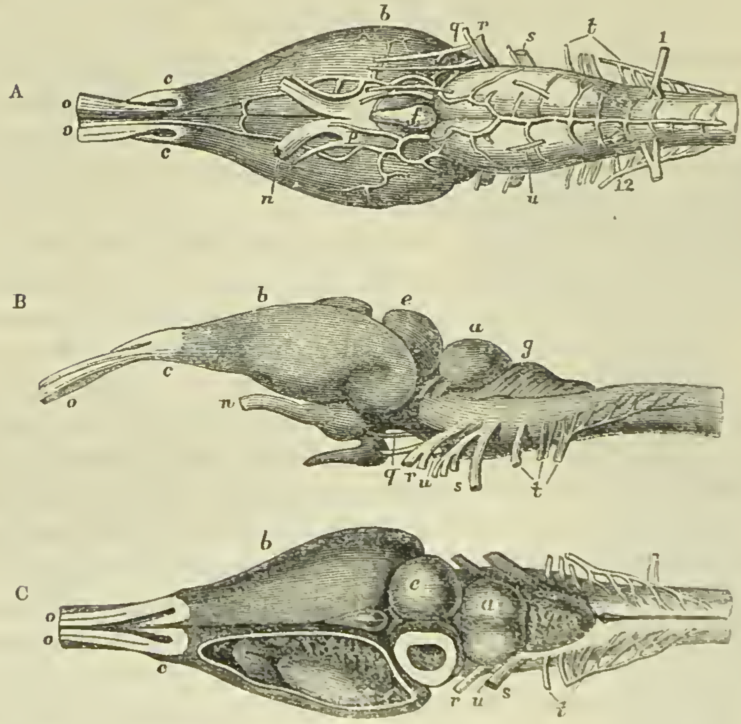
(1974.) It is, therefore, only necessary in this case to dilate the pulmonary vein previous to its termination, to make a heart with two auricles; but, as Professor Owen observes, the same advantage is secured to the Lepidosiren in a different manner; for, while it still retains the diœcious type of the heart of the fish, the continuation of the pulmonary vein prevents the admixture of the respired with the venous blood until both have arrived in the ventricle.

(1975.) The *aorta*, or, rather, the bulbus arteriosus (*g*), in this interesting creature, fulfils at once the office of a systemic, a branchial, and a pulmonary artery. It gives off on each side six vessels, which correspond to the six cartilaginous branchial arches; of these arches four, namely the 1st, 4th, 5th, and 6th, support gills, so that the arteries belonging to them (1, 4, 5, 6) are, as in fishes, distributed over the branchial fringes, and are thus true or functional branchial vessels. But the 2nd and 3rd arches have no gills appended to them; so that the arteries (2, 3,) belonging to these arches do not divide, but are continued round to the dorsal region, where they unite to form an aorta, as in *Menopoma* (fig. 343); moreover, before their union to form tho systemic trunk, they give off the pulmonary arteries (*l*, *m*) by which the pulmonary circulation is supplied. Thus each contraction of the ventricle of the heart drives the mixed blood derived from tho venæ cavæ and pulmonary veins, first, to the gills; secondly, to the aorta, through the vascular trunks (2, 3); and thirdly, to the lungs, through tho pulmonary artery (*l*, *m*); so that from this arrangement, whether the creature be placed in water or in air, respiration is carried on efficaciously either by the pulmonary or branchial apparatus vicariously.

(1976.) The principal difference observable between the brain of Reptiles and of Fishes is the increased proportionate size of the cerebral hemispheres (fig. 347, *b*); but they are still extremely small when compared with the bulk of the body. The appended figure (fig. 348), which represents the brain of the Tortoise in three different aspects, may easily be compared with that of the fish already given. The olfactory lobes (*c*) might now be mistaken for prolongations of the anterior extremity of the hemispheres; they contain distinct ventricles, and of course give origin to the olfactory nerves (*o o*). The hemispheres (*b*) are much more developed than in the last class; their surface is always smooth and without convolutions; and they are hollowed out into capacious ventricular chambers, in which are contained the *corpus striatum* and *choroid plexus* (fig. 348, c), and the two sides are moreover brought into communication by an anterior and posterior commissure.

(1977.) The optic lobes (*e*) are as yet uncovered by the extension of the hemisphere backwards, and each, when laid open, is found to enclose a ventricle (fig. 348, c). The cerebellum (*a*) is still small, and consists but of the median portion: behind it is a supplementary lobe (*g*), extending over the fourth ventricle, as in Fishes. The student will easily recognize the *pituitary body* (*f*); but neither this nor the origins of the nerves present any peculiarity worthy of more particular description.

Fig. 348.



Brain of the Tortoise.

(1978.) Taking the cerebral nerves in the order in which they arise, we will now proceed briefly to trace their general distribution; and this we shall find to correspond most exactly in all essential points throughout the different classes of Vertebrata.

(1979.) The olfactory nerves leave the olfactory lobes of the brain as single round cords, and are not, as in the Mammalia, divided into numerous filaments; consequently there is no cribriform plate to the ethmoid bone, but the nerve of each side (fig. 350, *e*) is received into a simple canal, partly osseous and partly cartilaginous, through which it is conducted to the cavity of the nose.

(1980.) The nasal apparatus of Reptiles differs from that of Fishes in one important particular. Breathing air as these creatures do, the sense of smell now becomes connected with the respiratory function; and a communication being established between the nasal cavities and the larynx, the air which passes through this channel into the lungs must necessarily come in contact with the sentient surface formed by those portions of the lining membrane of the nose to which the nerves of smell are distributed; and in proportion as the extent of that surface becomes developed, the power of appreciating the presence of odorous particles in the atmosphere will necessarily be increased. The physiologist is thus enabled to estimate with great exactness the relative perfection of the sense of smell in different classes, or even in different families of the air-breathing Vertebrata, simply by observing the complication and extent of surface presented by the lining membrane of the olfactory organ.

(1981.) Taking this as our guide, we must suppose that in all reptiles the sense in question is extremely obtuse, since in these creatures there are neither turbinated bones nor ethmoidal plates as yet distinguishable,—a few folds of the membrane lining the nose, even in those species which are most highly gifted in this particular, being the only provision for extending the olfactory surface; and in many cases, as for example in the Amphibia, the nose seems merely a simple canal leading into the mouth.

(1982.) On reaching the nasal cavity, the olfactory nerve spreads out into delicate filaments (fig. 350, *d*), which are distributed to the Schneiderean membrane covering the *septum* and upper part of the nose.

(1983.) The optic nerves of Reptiles (fig. 348, *n*), soon after their origin, become confounded together by a commissure, in the same way as in the human subject; and again separating, they are continued through the optic foramina to the eyes.

(1984.) The eyeball itself presents few peculiarities in its structure. In the Tortoise, and many Lizards, the sclerotic contains a circle of bony plates imbedded in its substance, and surrounding its anterior margin: these are obviously the rudiments of that osseous zone which in the class of Birds, as we shall find, performs a very important office. The ciliary processes of the choroid are generally very feebly developed. The pupil is frequently round; but it is sometimes of a rhomboidal figure, as for example in the Gecko; and in the Crocodile and some Serpents the pupillary aperture is a vertical fissure like that of a Cat.

(1985.) The optic nerve enters the eye in the same way as in quadrupeds, and, having passed the choroid, it terminates in a round papilla, from the margin of which the retina spreads out. As to the rest, the eye of a Reptile differs so little in any essential circumstance from that of Man as to render any more elaborate description superfluous.

(1986.) The eyeball is moved by six muscles, disposed as in Fishes, —the four *recti* arising from the margin of the optic foramen, while the two *obliqui* are derived from the anterior margin of the orbit.

(1987.) In Fishes, from the circumstances under which they live, there is no occasion for the presence of any lacrymal apparatus, or for eyelids adapted to defend and moisten the surface of the cornea; but in the class before us, especially in the more elevated tribes, these appendages to the eye make their appearance, and gradually assume a complexity of structure even greater than that which they present in the human subject.

(1988.) In Serpents, and in some of those Lizards which are most nearly allied to the Ophidians, there are still no eyelids; and consequently in such genera there can be neither any lacrymal apparatus nor a *conjunctiva,* properly so called; the skin of the head merely passes like a delicate film over the transparent cornea, offering no fold worthy of the name of an eyelid.

(1989.) In ordinary Lizards* the skin forms a kind of veil stretched over the orbit, and pierced by a horizontal fissure, which is closed by a sphincter muscle. The lower eyelid is the most moveable, and encloses a small cartilaginous plate; and there is, besides, generally a fold of the conjunctiva at the inner canthus of the eye, which is the first appearance of a third eyelid or *membrana nictitans.*

(1990.) In the Chelonian Reptiles and in the Crocodiles, the upper and lower eyelids are sufficiently perfect accurately to close the eye; but there are no eyelashes as yet present. Moreover these animals possess an additional eyelid or nictitating membrane, similar to that of Birds, which can be drawn at pleasure over the front of the eye, so as entirely to conceal it. This is effected by a special muscle provided for the purpose, which arises from the posterior part of the globe of the eye, and, after winding round the optic nerve, passes beneath the eyeball, to be inserted into the free margin of the membrana nictitans. In Frogs and Toads the upper and lower eyelids are nearly motionless; but the third is largely developed, and moved in the same way as that of the Crocodile.

(1991.) In the higher Reptilia a distinct lacrymal gland and *puncta lacrymalia* are met with, occupying the same positions as those of the human subject.

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* Cuvier, Leçons d'Anat. Comp. tom. ii. p. 433.

(1992.) The *third, fourth,* and *sixth* pairs of the cerebral nerves have the same distribution in all the Vertebrata, and represent respectively the *oculo-muscular,* the *pathetici,* and the *abducentes* of Man.

(1993.) The nerves belonging to the fifth pair likewise correspond both in their distribution and office with the trifacial nerves of mammiferous Vertebrata.

(1994.) The *facial nerve,* or *portio dura* of the seventh pair, is small, in proportion to the limited development of the soft parts of the face, but it is constantly present.

(1995.) The auditory nerve, of course, is destined to the ear, and its distribution is almost the same as in Fishes; nevertheless, in the general construction of the organ of hearing, Reptiles present very important and interesting advances towards a higher form of the acoustic apparatus, which we must proceed to notice.

(1996.) The ear of Fishes, being only adapted to hear sounds conveyed through a watery medium, was found to consist only of the membranous labyrinth, enclosed in the cavity of the skull, and without any communication with the exterior of the body. Reptiles, on the contrary, living in air, must be enabled to appreciate the sonorous vibrations of the atmosphere, and are consequently provided with an auditory apparatus capable of responding to pulsations of sound of far greater delicacy than those transmitted through the denser element.

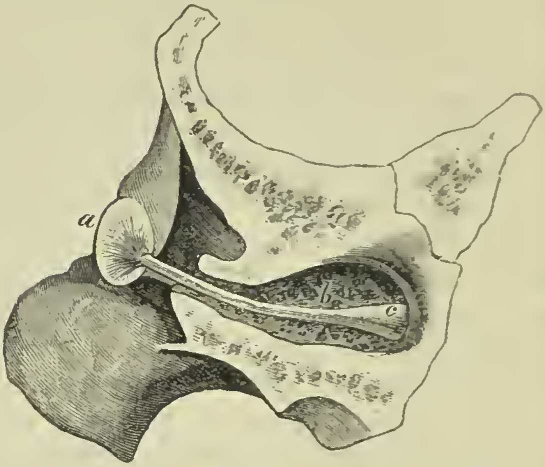
(1997.) The first great improvement, therefore, which the anatomist notices in the composition of the ear of a Reptile, is the addition of a tympanic cavity, and of a tense and delicate membranous drum, the vibrations of which are communicated to the labyrinth or internal ear through the intervention of an ossicle that represents the *stapes* of Mammalia.

(1998.) The drum of the ear is situated immediately beneath the skin, the parts composing the external ear of quadrupeds being as yet entirely deficient. The *membrana tympani,* that now for the first time makes its appearance in the series of animals, is tensely stretched across the tympanic aperture, being covered externally by the integument of the head. In the Turtle (fig. 349) the tympanic membrane is represented by a cartilaginous plate (*a*). The ossicle, or *columnella* as it is here called, is single and trumpet-shaped; it passes quite across the tympanic cavity (*b*), its external extremity being inserted into the drum, while at its opposite end it expands into a disk (*c*), which closes an aperture (*foramen ovale*) that communicates with the membranous vestibule of the internal ear. It is obvious, therefore, that every tremor impressed upon the *membrana tympani* will be conveyed by the *columnella* to the *foramen ovale,* and thus communicated to the fluid contained in the labyrinth, upon which, as in fishes, the auditory nerve is distributed.

(1999.) The cavity of the tympanum communicates with the interior of the mouth by a wide opening, that represents the Eustachian tube,—

a circumstance evidently intended to prevent air or fluid from being pent up in the tympanic chamber and thus interfering with the free vibration of the drum.

Fig. 349.



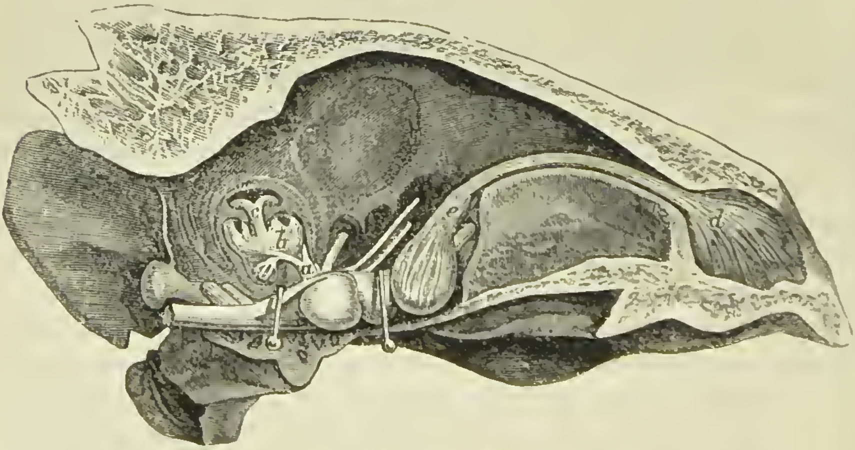
Ear of the Tortoise.

(2000.) In Serpents, on account of the peculiar disposition of the pieces of the temporal bone, before described (§ 1907), there is no tympanic cavity, and the *columnella* (fig. 335, *v*) is absolutely imbedded in the flesh; the arrangement, however, in other respects is the same as in the generality of reptiles.

(2001.) The lower tribes of Amphibia, as we might be led to expect from their close approximation to Fishes, have neither tympanum nor columnella, and thus, like Fishes, can only hear in an aquatic medium.

(2002.) The membranous labyrinth of Reptiles (fig. 350, *a*, *b*, *c*) corresponds in its general conformation with that of Fishes, presenting the same semicircular canals, ampullæ, and vestibular cavity, and moreover the sacculus contains cretaceous concretions or otoliths of a similar character; but in this class the membranous canals become enclosed in a bony sheath, moulded as it were upon their outer surface.

Fig. 350.



Auditory and olfactory apparatus of the Turtle.

which is another very important step towards perfecting the auditory apparatus.

(2003.) Neither must we omit to mention that in the highest of the Reptilia, as for example in the Crocodile, the first rudiment of a *cochlea* makes its appearance, although as yet in a form of extreme simplicity. This portion of the organ of hearing, which, from the elaborate structure that it presents in the higher Vertebrata, must be regarded as being importantly connected with correct audition, is seen in this the earliest stage of its development to be a simple conical appendage to the sac of the vestibule; and on opening it, it is found to be divided by a central cartilaginous septum into two compartments, which are, however, continuous with each other at the apex of the cone. One of these compartments or canals opens at one extremity into the vestibule, while the other communicates with the tympanic cavity by a very small aperture closed with a thin membrane. Thus, therefore, although the entire organ resembles a simple canal bent upon itself, the representatives of the *scala vestibuli*, of the *scala tympani*, and of the *fenestra rotunda* of the human ear can be distinctly identified.

(2004.) The *glosso-pharyngeal* and *pneumogastric nerves* in Reptiles supply the same organs to which they are distributed in the human subject, the former being destined to the base of the tongue and the muscles of the pharynx, while the latter, assuming a plexiform arrangement, are appropriated to the lungs and heart, as well as to the œsophagus and the stomach.

(2005.) The hypoglossal pair of the cerebral nerves, which was not met with in fishes, now becomes distinctly apparent, and, as in the higher Vertebrata, may be traced in the muscles of the tongue.

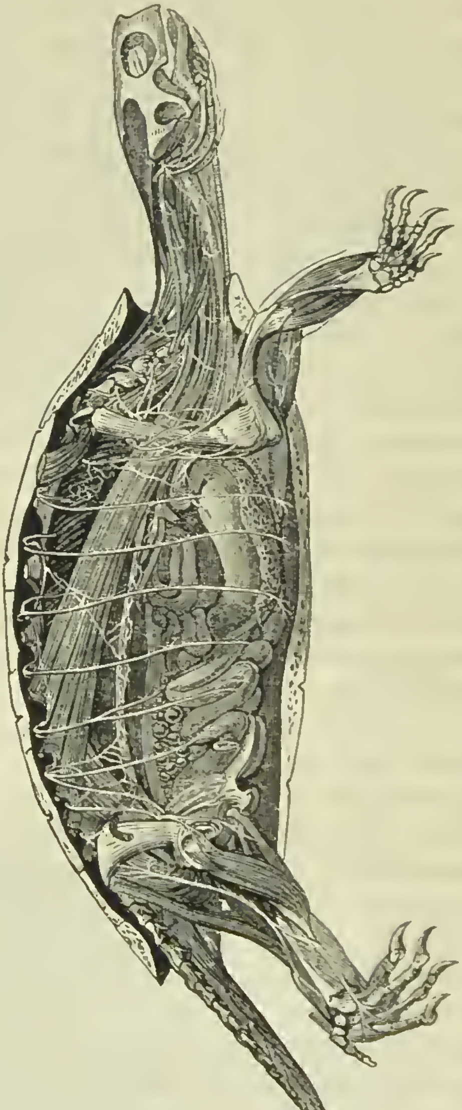
(2006.) The spinal system of nerves offers no peculiarity worthy of special description. In the annexed figure, taken from Bojanus, the nerves derived from the *medulla spinalis* are seen to issue in the usual manner from the intervertebral foramina; and they evidently essentially correspond with the grand type of structure common to the vertebrate classes. In the apodous Reptilia, as for example in the Serpents, to attempt to divide them into the usual regions is clearly absurd; but in quadrupedal forms, as for instance in the Tortoise, the cervical nerves, the brachial plexus, from which are derived the nerves of the anterior extremity, the intercostal nerves, and those forming the lumbar and sacral plexuses are at once distinguishable, and the correspondence between their distribution in the reptile and in the human subject must forcibly strike the student who makes the comparison.

(2007.) Neither does the *sympathetic system* of the Reptilia offer any important aberration from that arrangement with which the human anatomist is familiar. The ganglia are smaller in their proportionate size; those, indeed, of the neck and face are scarcely perceptible; but the thoracic ganglia are found in their usual positions, communicating on the one hand with the spinal nerves, and on the other giving off filaments which form plexuses around the arterial trunks, and ramify extensively to be distributed to the viscera.

(2008.) The sense of touch in all the members of the class under consideration must, from the nature of their integument, be extremely imperfect: many of them, in fact, as for example the Serpent tribes, are absolutely deprived of any limbs which can be regarded as tactile organs; and even in those forms which are provided with efficient locomotive extremities, these are but ill adapted to exercise the functions of an apparatus of touch.

(2009.) The cuticular investments of the body are formed of dense and unyielding materials, consisting, in the higher Reptiles, of broad horny plates or of imbricated scales. In the Amphibia, indeed, the skin is smooth, and the epidermis only forms a delicate corneous film; yet even in these the cuticle is thrown off at certain seasons of the year, as the old coat becomes too small for the increasing size of the animal, a phenomenon which in the Lizard and Serpent tribes is still more remarkably witnessed; for these animals strip themselves of their old scales as the hand would be drawn out of a glove, and cast away in one piece the entire epidermic integument, even to the film which covers the transparent cornea of the eye.

Fig. 351.



Nervous system of the Tortoise. (After Bojanus.)

(2010.) The urinary excretion in Reptiles becomes of very considerable importance, and the structure of the kidneys and excretory ducts proportionately elaborate. The kidneys (fig. 353, O, P) are generally situated very far back, even within the cavity of the pelvis where a sacrum exists, as in the Chelonian and Saurian orders; and in these tribes they are very partially covered by the peritoneum, being firmly imbedded in the sacral region. But in the Serpents, in consequence of the elongated form of the body and the complete flexibility of every portion of the spine, the kidneys are peculiar both in their position and general structure. Instead of being placed upon the same level as in other Vertebrata, the right kidney of an Ophidian is situated much more anteriorly than the left,—a circumstance which much facilitates the packing of the abdominal viscera, and contributes greatly to ensure the free movements of the vertebral column at this place. For the same reason, the kidneys of a Serpent are divided into numerous lobes, placed in a longitudinal series upon the outer side of the commencement of the ureter, and loosely connected to each other and to the spine by cellular tissue and a fold of the peritoneum.

(2011.) As relates to the minute structure of the kidneys in the Reptilia, these viscera are invariably composed of convoluted tubes, which pour their secretion into the commencement of the corresponding ureter. The ureters, of course, vary in length according to the position of the renal organs; they ultimately terminate in the *cloaca* (fig. 353, *u*)—a cavity or general outlet through which, in the female, the ova, the fæces, and the urine are discharged, and which in the male gives passage to the contents of the rectum, the secretion of the kidneys, and the semen.

(2012.) In connexion with the urinary apparatus of Reptiles, it will be convenient to mention a bladder that exists in Chelonian and Amphibious reptiles, and is also found in some Saurian tribes, to which the name "*urinary bladder*" has been erroneously applied. This bladder, in the Tortoise (fig. 353, A) and Proteus (fig. 340, *q*), is of considerable size, and in the Frog forms a very capacious receptacle, having its upper part divided into two cornua. It is generally filled with a clear limpid fluid, which in the case of the Frog is forcibly ejected if the animal be alarmed; but that this fluid is not urine is obvious from the fact already stated, that the ureters open into the cloaca (fig. 353, *u*), and not into the bag referred to; the latter, in fact, is the unobliterated remains of the *allantois* of the embryo, concerning which further particulars will be given in the next chapter, and the fluid contained in it is most probably the product of cutaneous absorption*.

(2013.) In tracing the development of the generative apparatus through the different orders of Reptiles, the student will not fail to observe many beautiful illustrations of progressive improvement.

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* *Vide* Cyclopædia of Anatomy and Physiology, art. AMPHIBIA, by Professor Bell, p. 104.

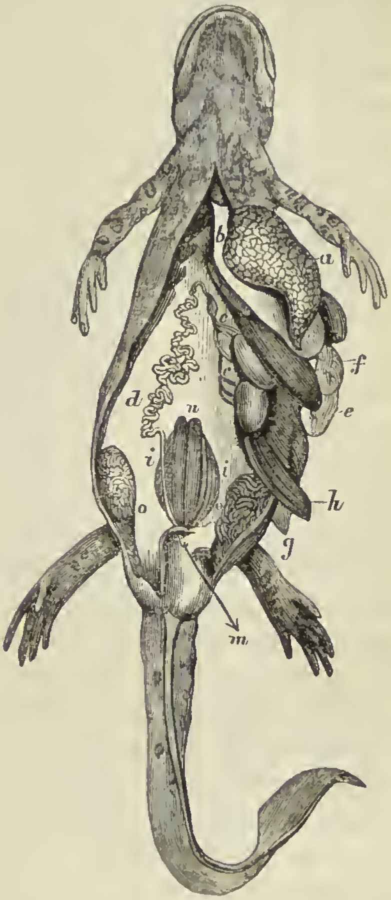
(2014.) The finny tribes, incapable of social intercourse, were content with the simple extrusion of their eggs into the sea, leaving them to be impregnated by the casual approach of a male of the same species; but even in the Amphibious reptiles some steps are gained in associating the sexes with each other; and although the eggs are still impregnated out of the body of the mother, in the Frog this is accomplished *in exitu*, and not subsequent to their expulsion.

(2015.) Frogs, during the breeding-season, are found to pair, and the male having selected his mate mounts upon her back, clinging to her with unwearying pertinacity during the whole period of oviposition, and vivifying her eggs by the aspersion of the seminal secretion as they are successively expelled in long gelatinous chains. During this protracted embrace the male Frog is assisted in retaining his hold by the development of a peculiar papillose structure upon the first toes of the fore-feet, which disappears at the end of the time appropriated to reproduction. Of course no intromittent apparatus is as yet required, and we may naturally expect to find the male organs still exhibiting great simplicity of construction.

(2016.) The testes and their excretory ducts, in fact, are the only parts as yet met with; but the anatomy of these parts, although most accurately investigated by Swammerdam upwards of a century ago, is still very generally misunderstood. The testicles are situated in the loins, surrounded by several tongue-like masses of fat presenting a peculiar granulated appearance. Each testis is invested by a delicate capsule, and on removing this very carefully, the entire viscus is seen to be made up of short cæca, the blind extremities of which alone appearing at the periphery of the organ caused Cuvier to describe it as being "an agglomeration of little whitish grains interwoven with blood-vessels." The semen elaborated by these cæca is taken up by several small excretory ducts that pierce the kidney, in the immediate vicinity of which the testis lies, and open into the *ureter*, that here forms the common excretory duct, whereby the urine as well as the seminal fluid is discharged, both escaping into the cloaca at a little distance from the orifice of the allantoid bladder, to be ultimately ejected through the vent.

(2017.) Neither is the generative system of the female Frog less worthy of notice. The ovaria resemble in their essential structure those of the Lamprey (§ 1846); only they are much less extensive, consisting of a few festoons of the highly vascular membrane wherein the ova are secreted, fixed at the pelvic extremity of the abdominal cavity. On each side of the body is a long and very tortuous oviduct, which when unravelled is found to be many times the length of the animal. The fimbriated commencement of this oviduct is firmly bound down by folds of peritoneum in the immediate vicinity of the pericardium, and, of course, as remote as possible from the ovary: it therefore becomes a question of no inconsiderable interest to determine the manner in which the ova are conveyed from the ovarian nidus to the orifice of the oviduct. It is obvious that they must first break loose into the abdominal cavity, as we found them to do in the Lamprey and the Eel, and that at length, having made their way into the neighbourhood of the pericardium, they are seized by the patulous extremity of the Fallopian tube, and thus conveyed out of the body. As the ova make their transit through the oviduct they become imbedded in a tenacious albuminous secretion, and are at length lodged in a dilated portion of the tube, to which the name of uterus has been very improperly given, preparatory to their expulsion through the cloaca. After the eggs have been discharged into the surrounding water, the albuminous mass in which they are imbedded swells considerably; and when the young tadpoles are hatched, this material no doubt serves to nourish them during the earlier period of their existence.

Fig. 352.



Generative organs of male Salamander.

(2018.) In the Newt (*Triton*) impregnation takes place internally, although the male is still without any rudiment of an intromittent apparatus, so that we are compelled to believe that in the case of these Amphibia the simple ejection of the male fluid into the water in the vicinity of the female is sufficient to ensure its admission to the ova while still in the oviduct. An improvement is likewise visible in the construction of the internal viscera subservient to generation; and a *vas deferens*, quite distinct from the ureter, makes its appearance. In the male Salamander (*Triton cristatus*) the testis during the breeding-season consists of two pyriform masses, from which the seminal ducts (fig. 352, *c c*) are derived. These soon unite to form a single convoluted tube (*d*), through which the semen is conveyed into the cloaca. The kidneys (*n*) and their excretory ducts (*i i*) are here placed considerably further back; but the ureters terminate in the cloaca at the same point (*m*) as the vasa deferentia. Two other large glands (*o o*) are apparently connected with the generative functions, and their excretory ducts likewise open into the cloacal outlet.

(2019.) In the female Triton, as also in the Proteus and Siren, the ovaria and oviducts offer precisely the same arrangement as that met with in the Frog, already described *.

(2020.) In the Ophidian, Chelonian, and Saurian orders, the testes of the male sex are situated in the loins; and in fact they occupy the same position throughout the oviparous Vertebrata: they offer no peculiarity of structure, only differing from those of the Frog in the increased length of the now contorted seminal cæca of which they are essentially composed. From each testis a long and flexuous *vas deferens* conducts the semen into the cloaca. Here, however, in these more elevated forms of the Reptilia, we have another important addition to the male sexual apparatus—instruments being given to facilitate the impregnation of the female during that union of the sexes which now becomes essential to fecundity. The earliest appearance of the copulatory organ is seen in Serpents and in the Lizard tribes; and in such reptiles it will be observed that the penis is rather a provision for securing the juxtaposition of the sexual apertures of the male and female than an instrument of intromission. The two lateral halves of the penis (or *corpora cavernosa*, as we shall have to call them hereafter, when they become conjoined in the mesial line) are as yet quite separate, and placed at each side of the cloacal fissure, from which they protrude when in a state of erection, so that there appear to be two distinct organs of excitement, or, more properly speaking, of prehension; for each division, being of course imperforate, is covered with sharp spines, and is obviously rather adapted to take take firm hold of the cloaca of the female than to form a channel for the introduction of the seminal fluid.

(2021.) In the Chelonian Reptiles the penis is much more perfectly developed, and really constitutes a very efficient intromittent instrument. The two corpora cavernosa, after commencing separately, approach each other, and become united along the mesial line so as to form a single organ of considerable size, terminated at its extremity by a glans-like dilatation. There is, however, no *corpus spongiosum*, nor urethral canal, properly so called: the latter is represented by a deep groove, which runs along the upper surface of the penis from the cloaca to the extremity of the organ; and it is along this groove that the spermatic fluid is conveyed during coitus.

(2022.) On making a section of this strange apparatus, two canals are discovered, running one on each side of the central furrow, along the whole length of the organ as far as the glans, where they terminate without at all communicating with the exterior; but on tracing them in the opposite direction, they are found to be derived from the peritoneal cavity, into which they open by distinct orifices †.

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* *Vide* Rusconi, Observations anatomiques sur la Sirène, mise en parallèle avec le Protée et le Têtard de la Salamandre aquatique. Pavie, 1837.

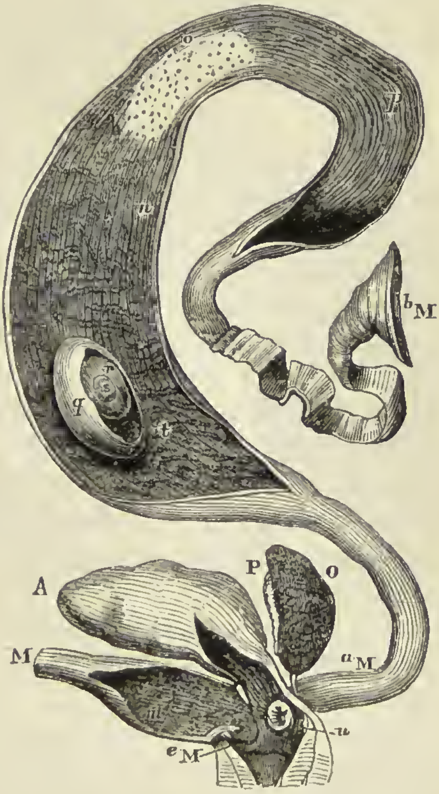
† Cuvier, Anat. Comp. tom. v. p. 115.

(2023.) Two retractor muscles, derived from the pelvis, and extending along the under surface of the penis quite to its extremity, fold the whole organ back into the cloaca, where it lies concealed when not in use.

(2024.) In the Crocodiles and higher Saurians the penis in its structure resembles that of the Tortoise; and instead of a urethra, there is merely a deep groove traversing the upper surface of the organ, along which the semen trickles out of the cloaca.

(2025.) Throughout all the Reptile families the organization of the female generative system is so extremely similar, that one example will be abundantly sufficient for our purpose, the same description, in fact, being equally applicable to the Saurian, the Chelonian, and the Ophidian orders. The ovaries occupy their ordinary position in the lumbar region of the abdomen, where they are attached on each side of the vertebral column by a broad fold of peritoneum: their structure is in all essential points precisely similar to those of the Amphibia; but, owing to the increased proportionate size of the individual ova formed by their vascular membrane, they resemble a string of beads, or assume somewhat of a racemose appearance. The oviducts are long and flexuous; they commence by a wide orifice (fig. 353, *b* M), by which the germs are taken up from the ruptured ovisacs of the ovaria in the same way as those of Mammalia are seized by the fimbriated extremities of the Fallopian tubes. The first portion of the oviduct is thin and intestiniform; but lower down, where the investments of the egg are formed, its walls become thicker, and assume a glandular character (*n*, *o*, *p*); they finally open into the cloaca; and the mode of their termination in the Tortoise is exhibited in the accompanying figure, where M, *m*, *e* M indicate the terminal portion of the right oviduct laid open, the left (*a* M, *b* M) being shown through its entire length.

Fig. 353.



Oviduct and ovum of female Tortoise. (After Bojanus.)

(2026.) The formation of the egg and the development of the embryo are similar in all the oviparous Vertebrata; it will therefore be more convenient, and prevent unnecessary repetition, if we defer the consideration of this important subject to the next chapter,—the reader bearing in mind that in all essential particulars the details which will be given there, when we come to consider the growth of the Bird *in ovo*, are equally applicable to the Chelonian, Ophidian, and Saurian Reptiles.

CHAPTER XXVIII.

AVES—BIRDS.

(2027.) The class of Vertebrate animals which now offers itself to our notice contrasts remarkably with the cold-blooded and apathetic inhabitants of the water, and even with the slow-moving Reptile, that languidly crawls upon the surface of the ground, or drags on an amphibious existence in the marsh or on the shore. The Bird, ordained to soar into the regions of the air, and not only to sustain itself in that thin medium, but to skim from place to place with astonishing rapidity, needs a strength of muscle and activity of limb even greater than that conferred upon the mammiferous quadruped. Senses of the utmost acuteness are now requisite, combined with instinct and intelligence of a high order; and accordingly, both as regards their faculties and enjoyments, the feathered tribes far surpass the other oviparous Vertebrata.

(2028.) Next to that improvement in the condition of the nervous system, which we have all along been able to trace advancing *pari passu* with the increase of sagacity and the expansion of the bodily faculties, the most remarkable circumstance observable in the economy of Birds is the elevated temperature of their bodies and the heat of their circulating fluids. In the Reptile an impure and semioxygenized blood was slowly propelled through the system from the undivided ventricle of their trilocular heart, and we found their energies, their instincts, and their affections proportionately feeble and obtuse; but now, not only does the heart become divided into four cavities (one ventricle being appropriated to transmit venous blood to the lungs, while the other drives a pure and highly-arterialized fluid in copious gushes to the remotest regions of the body), but, as though even this was not sufficient to meet the necessities of the case, the whole interior of the Bird is permeated by the atmospheric air, which penetrates even into the bones; and the respiratory function being thus rendered as complete as possible, all parts of the muscular system are abundantly supplied with blood arterialized to the utmost, and every fibre, quivering with life intense, is ready to exert that vigorous activity which brings down the falcon upon his quarry like a thunderbolt from the clouds, or sustains the migratory bird through long and perilous journeyings.

(2029.) But increase of muscular energy is by no means the only consequence resulting from more perfect respiration and a consequently increased temperature of the blood: the clothing of the body must now be changed for a warmer covering than scales or horny plates; feathers are therefore at once provided, as the lightest, warmest blanket that could be given: maternal care, which to the cold-blooded Ovipara would have been a useless boon, can now be beneficially exercised; the eggs, no longer left to chance, are cherished by the vital heat of the parent; and the callow brood, during the first period of their lives, are dependent for support upon the watchful attentions of the beings from whom they derived their existence.

(2030.) The skeleton of a vertebrate animal formed for flight must obviously be constructed upon mechanical principles widely different from any that have yet come under our notice. The utmost lightness is indispensable; but still, in a framework which has to sustain the action of muscles so vigorous, strength and firmness are equally essential: it is in combining these two opposite qualities that the human mechanician displays the highest efforts of ingenuity, and by the scientific disposition of his materials exhibits the extent of his resources and the accuracy of his knowledge; but let the best-informed and most ingenious mechanic carefully and rigidly investigate the skeleton of a bird, and we doubt not that in it he will find all his art surpassed, and derive not a little instruction from the survey.

(2031.) In the spinal column of a bird we find three principal regions, each of which will merit distinct notice.

(2032.) The anterior or cervical region is exceedingly variable in its proportionate length, and forms the only flexible portion of the spine: it performs, indeed, the office of an arm, at the extremity of which the beak, the chief instrument of prehension, is situated. The number of vertebræ entering into the composition of this part of the spinal column is very variable: in the Swan there are as many as twenty-three; in the Crane, nineteen; while in the little Sparrow nine only are met with: their bodies are joined together by articulating facets enclosed in synovial capsules, and not by the interposition of intervertebral substance; an interarticular cartilage, however, is generally met with, by which the movements of the chain are facilitated. The spinous and transverse processes are short; while the oblique processes, united by articulating surfaces, limit the mobility of the neck.

(2033.) Although this portion of the spine is very properly designated the "cervical region," we are not on that account to imagine that the vertebræ composing it are unprovided with ribs: on the contrary, rudimentary costal appendages are generally found connected with their transverse processes, which, in the young bird, are obviously separate elements, although they afterwards become united by anchylosis.

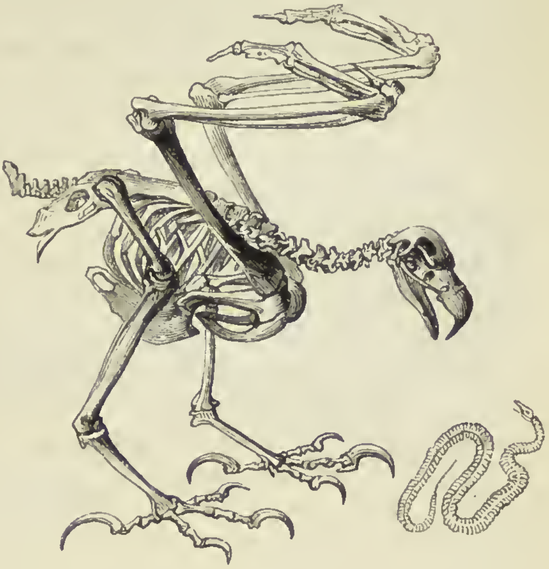
(2034.) But if flexibility is thus abundantly provided for in the cervical portion of the vertebral column, it is quite evident that in the thoracic portion of the skeleton, which has to support the framework of the wings, and sustain the efforts of the muscles connected with flight, firmness and rigidity become essential requisites; and accordingly everything has been done to prevent those movements which in the neck were so advantageously permitted. The bodies and spinous processes of the contiguous vertebræ are therefore here firmly consolidated together by anchylosis; and, moreover, splints of bone, derived from the transverse processes, overlap each other and still further add to the stability and strength of the back.

(2035.) The ribs appended to the dorsal vertebræ may be called the true ribs; these enter into the composition of the thorax, and materially assist in strengthening that region. Each rib, as in the Crocodile, presents a dorsal and a sternal portion, connected together by a joint: the former are attached to the vertebræ by a double articulation, their spinal extremity being furcate; while the latter are articulated to the sides of the sternum. A thorax is thus formed, possessing sufficient mobility to perform the movements connected with respiration, but still affording a strong basis to support muscular action; and in order to give the greatest possible strength, from the posterior margin of each dorsal rib a broad flat process is prolonged backwards and upwards to overlap the rib next behind, so as in this manner to bind the whole together into one strong framework.

(2036.) The sternum itself is developed in proportion to the enormous size of the three pectoral muscles which constitute the great agents in flight: it is principally composed of the central azygos element before noticed in the Tortoise, which is here remarkably dilated, and in birds of flight prolonged inferiorly into a deep keel-like process, so as to increase materially the extent of surface from which the muscles of the breast take their origin; but in the cursorial genera, such as the Ostrich, the Emeu, &c., where the wings are not available for flying, the keel is entirely wanting, and the sternum forms merely a kind of osseous shield, covering comparatively a very small portion of the breast.

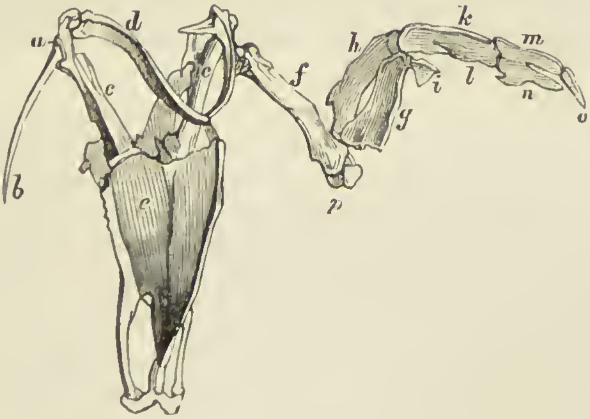
(2037.) Whoever considers the position of the hip-joint in the feathered tribes, and reflects how far it is necessarily removed behind the centre of gravity when the bird walks, carrying its body in a horizontal position, will at once perceive that the pelvic portion of the spine, having to sustain the whole weight of the trunk under the most unfavourable circumstances, and at the same time to give origin to the strong and massive muscles wielding the thigh, must be consolidated and strengthened in every possible manner, and that even the slight degree of movement permitted in the dorsal region would here be inadmissible. The lumbar and the sacral vertebræ, and the entire pelvis, are therefore at an early period solidly united together by anchylosis into one bone, and the number of the vertebræ composing this part of the skeleton is only distinguishable from the situation of the intervertebral foramina through which the spinal nerves are given off. In very young birds the pelvis is evidently formed by the three elements that usually enter into its composition; and the *ilium*, the *ischium*, and the *pubis*, as well as the *ischiadic notch* and *obturator foramen*, will all be at once recognized by the anatomist, occupying their usual relative positions, although he will not fail to notice one remarkable circumstance, namely that, except in one instance (the Ostrich), the *ossa pubis* do not meet in front, so that there is no pubic arch or symphysis.

Fig. 354.



Skeleton of Eagle.

Fig. 355.



Wing of Bird.

(2038.) The anterior extremity of a bird, although an instrument of flight, is found, when stripped of those feathers and long quills that form the extensive surface presented by this member during life, still closely to adhere to the general type in accordance with which this part of the skeleton is invariably constructed. The framework of the shoulder exhibits the *scapula* (fig. 355, *b*), the *clavicle* (*d*), and the *coracoid* element (*c*), notwithstanding that these bones, forming, as they do, the basis of a limb so vigorous, and wielded by such powerful muscles, are necessarily modified in their form and general arrangement, so as to constitute strong buttresses adapted to keep the shoulder-joint firm and steady during flight. The *scapula* (*b*) is a long and slender bone placed upon the ribs, and lying parallel to the spine along the dorsal region of the thorax, imbedded in the muscles to which it gives attachment, while at its fixed extremity it assists in forming the cavity of the shoulder-joint. The *coracoid bone* (*c*) is the great support of the shoulder; for while at one extremity it sustains the wing, at the opposite it is firmly and securely united to the sternum by a broad articulation. But the most peculiar element of this apparatus is the *furculum*, or forked bone (*d*), composed of the conjoined clavicles, which, being anchylosed together in the mesial line, and also strongly connected with the shoulder-joint, materially add to the stability of the whole.

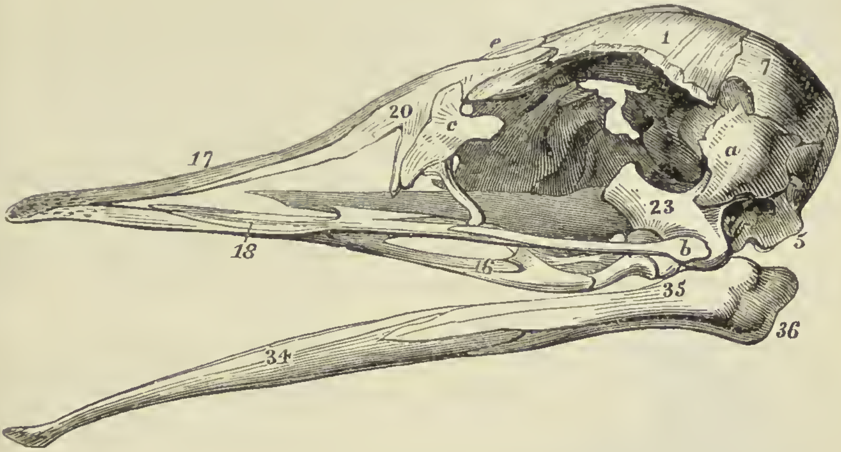
(2039.) In the wing itself, the *humerus* (*f*) is at once recognized, as also the *ulna* (*g*) and the *radius* (*h*). But in some birds, as in the Penguin, the student might be at a loss to identify one or two small bones (*p*), forming a kind of *patella* to the elbow-joint; these appear to be the representatives of the olecranon process detached from the ulna. The *carpus* (*i*) consists of only two small bones. The *metacarpus* is formed of two pieces (*k*, *l*), anchylosed together at their two extremities; and these, with two, or in some cases three rudimental fingers, complete the wing. The largest finger consists of two, or sometimes three phalanges (*m*, *o*); a second (*n*) offers but a single joint; and the third, which is a mere rudiment when present, is an appendage to the radial side of the carpus.

(2040.) In the pelvic extremity (fig. 354) the *femur* is a short and strong bone; to this succeeds the *tibia*, upon the outer side of which is fixed a rudimental *fibula*. The *tarsus* can scarcely be said to exist, being at a very early age confused with the *metatarsus*,—the whole forming a single tarso-metatarsal bone, which, in the Wading Birds especially, is of very great length: at its distal extremity are three articular surfaces that support the three anterior toes, while a fourth toe, the *hallux*, directed backwards, is attached to it posteriorly by the intervention of a small accessory piece; and in Gallinaceous Birds an osseous spur, consolidated with the posterior face of the tarso-metatarsal bone, is generally considered as a fifth toe.

(2041.) The number of toes varies in different tribes of birds. Thus, in the *Ostrich* there are only two; in many genera there are three: in by far the greater number, four; and in the *Gallinacea*, five. But whatever the number of toes may be, the number of phalanges peculiar to each is remarkably constant: thus, the outermost toe always consists of five phalanges; the fourth toe invariably of four; the third as constantly of three; the second, when it exists, has only two; and, lastly, in the *spur* or innermost toe there is but a single piece.

(2042.) So rapidly is the process of ossification accomplished in the skeleton of a bird, that it is only in very young animals the individual

Fig. 356.



Skull of a young Ostrich.

bones or elements composing the cranium can be identified, as the sutures speedily become obliterated: when, however, they are examined under very favourable circumstances, as for example in the skull of a young Ostrich, it is by no means difficult to distinguish them, and, by comparing them with those of other Vertebrata, to observe the modifications they have undergone both in form and position. In the annexed figure the principal pieces, both of the cranium and face, have been indicated by the same figures as were used to point out the correspondent bones in the skulls of the Crocodile (fig. 332) and the Serpent (fig. 335); so that it would be needless again to enumerate them in this place.

(2043.) The muscular system of the feathered tribes, as far as activity and energy of motion is concerned, contrasts strikingly with that of the Vertebrata we have as yet considered; for, with the exception of Insects, no animals in creation are comparable to Birds, either in the vigour or velocity of their movements.

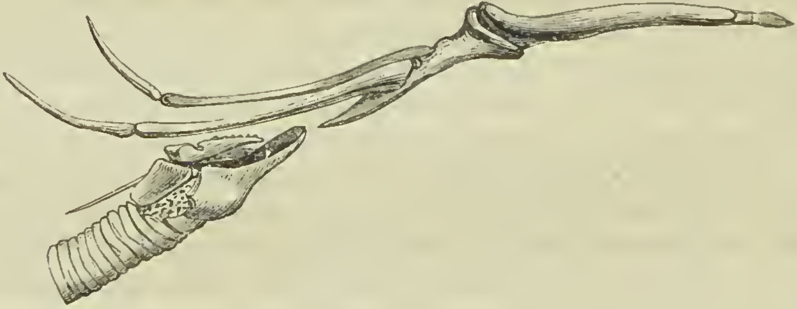
(2044.) This perfection of muscular power, which is obviously essential to enable the bird to sustain itself in the air, and there perform the varied evolutions connected with flight, is no doubt mainly connected with the highly arterialized condition of the blood and the completeness of the respiratory apparatus. Neither is it uninteresting to observe that, while respiration was effected in the Insect by the admission of air to every part of the system by means of tracheal tubes, in Birds likewise the air freely penetrates to the interior of the body, and, as we shall afterwards find, is there most extensively diffused.

(2045.) In the construction of the alimentary system, there are many interesting peculiarities to invite our notice. Their mouth constitutes the apparatus whereby the prehension of food is accomplished; it is in no instance provided with teeth, or adapted to masticate food, but forms a beak encased in a dense, horny sheath, which, from the varieties of form that it assumes in different genera, becomes adapted to very various purposes.

(2046.) In the Rapacious tribes, for instance, the bill is a strong and formidable hook, calculated to tear in pieces the animals devoured. In Granivorous birds, it is a simple forceps for picking up the seeds of vegetables. In the Snipe and the Curlew it forms a probe, whereby insects are extracted from the soft and marshy ground. In the Parrot it is partially an assistant in climbing, as well as an organ for seizing food; and, not to mention innumerable other modifications, in the Flamingo and Duck tribes it constitutes a shovel, by the aid of which alimentary matters are obtained.

(2047.) The sense of taste, even in these highly-gifted animals, is as yet but very imperfectly developed; and their tongue, instead of being soft and flexible, as in the Mammalia, is supported by one or two bony pieces, derived from the os hyoides (fig. 357), and covered with a horny sheath, obviously ill adapted to gustation, but simply assisting in the deglutition of food. We must not be at all surprised, therefore, if even in birds the tongue is convertible into various instruments assisting in the apprehension or preparation of nourishment: thus, in the Parrot it is a thumb opposable to the upper mandible, and eminently serviceable in holding and turning nuts or morsels of fruit; in the honey-eating tribes the tongue is armed at its extremity with a tuft of horny filaments, resembling a camel-hair pencil, which, being plunged into the bell of a flower, sucks up the nectar from the bottom; and in the Woodpecker it is absolutely converted into a harpoon, whereby the insect is speared in its lurking-place and dragged into the mouth.

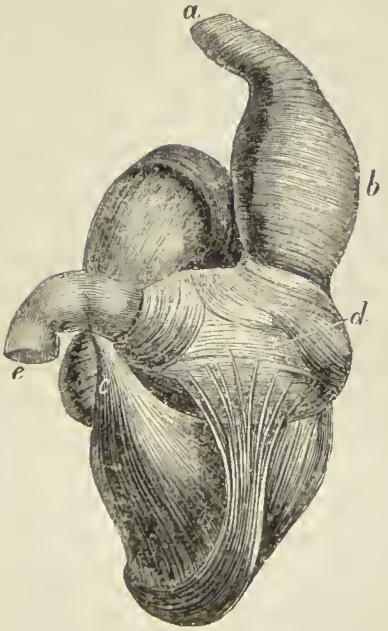
Fig. 357.



Hyoid apparatus of a bird.

(2048.) In most birds, in consequence of the very small size of the cavity of the stomach, or gizzard, as it is generally called, some other receptacle for the aliment becomes indispensable; and accordingly various provisions have been made for lodging food in sufficient quantities in situations where it may be retained until the gizzard is ready to receive it. In birds that catch insects on the wing, this is most conveniently effected by dilating the fauces and upper part of the throat into a capacious chamber, wherein the insects as they are seized accumulate: this is remarkably the case in the Swifts. In the Pelican a very peculiar plan is adopted: the beak is amazingly prolonged, and beneath the lower jaw is suspended a white pouch, formed by the skin of the throat, wherein large quantities of fish may be contained and carried about. In other fishing birds the whole œsophagus is extraordinarily capacious, and will hold a considerable supply; but the most usual arrangement in birds requiring such a reservoir is the existence of a *crop*, or dilatation of some part of the gullet into a wide bag (*ingluvies*), wherein grain or other substances hastily picked up may be stored preparatory to digestion. After expanding into the crop in those birds that possess this cavity, the œsophagus again contracts to its former dimensions (fig. 358, *a*); but just before terminating in the gizzard, it again dilates to form a second but smaller cavity (*b*), called the *proventriculus*, or *bulbus glandulosus*, in which the food undergoes further preparation. The walls of the proventriculus are thickly studded with large glandular follicles, variously disposed, from whence a copious secretion of "*gastric juice*," as it is called, is poured out and mixed with the aliment. Having, therefore, undergone maceration in the juices of the crop, and become subsequently saturated with the gastric fluid, that constitutes so important an agent in digestion, alimentary substances are at length received into the gizzard (*c*), where further preparation is necessary.

Fig. 358.



Gizzard of a bird.

(2049.) The gizzard in such birds as feed upon vegetable substances is an organ possessing immense strength, and constitutes, in fact, a crushing mill, wherein nutritive materials are bruised and triturated.

Its cavity is very small, and lined with a dense, coriaceous cuticular stratum; and its substance is almost entirely made up of two dense and enormously powerful masses of muscle, the fibres of which radiate from two central tendons (fig. 358, *c*), situated upon the opposite sides of the viscus. The action of these lateral muscles will obviously grind and crush with great force whatever is placed in the central cavity,—a process that is materially expedited by the presence of hard and angular pebbles, swallowed for the purpose, by the assistance of which the contained food is speedily comminuted.

(2050.) Another and much feebler set of muscles (*d*) bounds the cavity of the gizzard in the intervals between the great lateral masses which, receiving the food from the proventriculus, perpetually feed this living mill, and retain the material to be ground within the influence of the crushers until it is properly prepared, when other fibres, acting the part of a pylorus, allow it to pass on into the duodenum (*e*).

(2051.) The intestinal canal of Birds is, as in other classes, very variable in its relative length as compared with that of the body; its calibre is pretty equal throughout, and the division into large and small intestines can scarcely be said to exist. Commencing from the pylorus, the duodenum (fig. 359, *d h*) is always found to make a long and very characteristic loop, embracing the lobes of the pancreas (*e e*); and then, after sundry convolutions, the intestine is continued to its termination in the cloaca. The division between the large and small intestines is indicated by the presence of one, or more generally two, cæcal appendages, which communicate with the cavity of the gut at no great distance from its cloacal extremity.

(2052.) In Birds, the auxiliary secretions subservient to the digestive process are the salivary, the gastric, the hepatic, and the pancreatic.

(2053.) The salivary apparatus varies much in structure and disposition in different tribes. In its simplest form it consists of distinct secerning follicles, placed immediately beneath the mucous membrane of the mouth, into which the secretion is poured by numerous orifices. In the Gallinaceous birds the glands assume a conglomerate character. In the Turkey there are two pairs *: the first pair forms a cone, having its apex directed towards the extremity of the beak; and the two glands of the opposite sides touch each other along the mesial line through almost their entire length, filling up anteriorly the angle of the lower jaw. These glands are situated immediately beneath the skin, but in front they touch the mucous membrane of the mouth; and their secretion is poured into the buccal cavity by several orifices. The second pair of glands is smaller, of an elongated form, and is placed above the posterior third of the former; this is immediately in contact with the mucous lining of the mouth.

(2054.) In the Woodpeckers the glands that secrete the fluid whereby the tongue is lubricated are of very considerable size. They pass further back than the angle of the lower jaw, extending even to beneath the occiput; and their secretion, which is viscid and tenacious, enters the mouth by a single orifice situated under the point of the tongue.

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* Cuvier, Leçons d'Anat. Comp. tom. iii. p. 221.

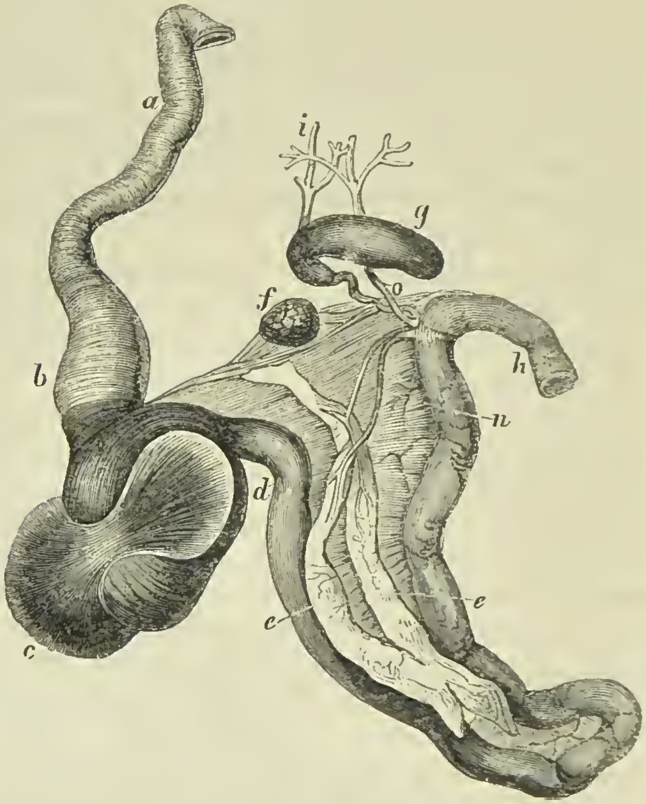
(2055.) In the generality of birds, however, there is only one pair of salivary glands; and these, in many cases, seem to be united into a single mass, separated posteriorly into two lobes, and situated beneath the palatine membrane, behind the angle of the rami of the lower jaw. From these glands a thick, white and viscid fluid is poured into the mouth through numerous orifices, principally disposed along the mesial line which separates the two glands.

(2056.) We have already spoken of the gastric glands which densely stud the coats of the proventriculus, and furnish the "gastric juice," and therefore pass on to notice the other subsidiary chylopoietic viscera, namely, the liver, the pancreas, and the spleen.

(2057.) The *liver* is a viscus of considerable magnitude, consisting of two principal lobes, and firmly suspended *in situ* by broad ligaments and membranous processes. The *vena portæ*, supplying that venous blood from which the bile is elaborated, is formed by vessels derived from numerous sources, receiving not only the veins of the stomach, spleen, and intestines, as in Mammalia, but likewise the renal and sacral veins,—another proof, if any were wanting, that no arrangement by which the decarbonization of the blood can be facilitated has been omited in the organization of the class before us. The hepatic arteries and the hepatic veins present nothing remarkable in their disposition; but the course of the bile from the liver into the intestine merits our notice. Two sets of ducts are provided for this purpose: the first (fig. 359, *i*) carries the bile from the liver into the gall-bladder (*g*), from which another duct conveys the bilious fluid into the duodenum; but the second set of bile-vessels conducts the secretion of the liver at once into the intestine, by a wide canal (*o*) that has no communication whatever with the gall-bladder. There is, therefore, no arrangement like that of the "*ductus communis choledochus*" of Mammals: if the bile is wanted immediately, it passes at once into the intestine through the duct *o*; but if digestion is not going on, it is conveyed into the gall-bladder through the duct *i*, to be there retained until needed.

(2058.) The *pancreas* (fig. 359, *e e*) is a conglomerate gland of considerable size, situated in the elongated loop formed by the duodenum: it generally consists of two portions more or less intimately connected, and from each portion an excretory duct (*n*) is given off; these two ducts terminate separately in the intestine, in the immediate vicinity of the openings of the biliary canals. In some birds even three pancreatic ducts are met with, as is the case in the common Fowl; but under such circumstances the third duct, instead of opening into the intestine at the same point as the other two, issues from the opposite extremity of the pancreas, and enters the middle of the duodenum at the place where the gut turns upon itself.

Fig. 359.



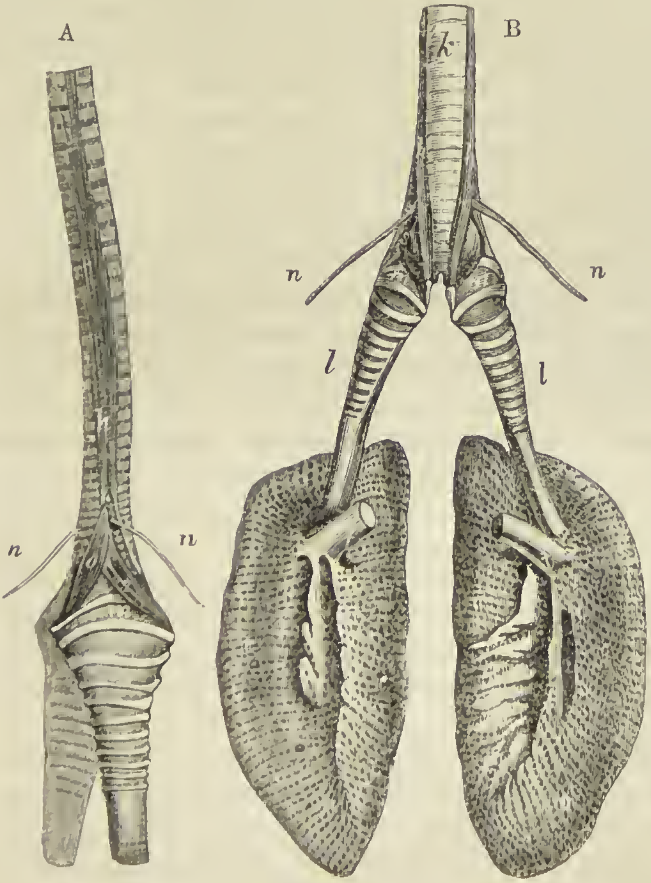
Digestive apparatus of a Fowl.

(2059.) The *spleen* (fig. 359, *f*) is of very small size in all birds; it is situated near the anterior extremity of the pancreas, and is loosely connected to the side of the proventriculus (*b*). The distribution of its vessels and its general structure are the same as in Mammalia.

(2060.) The lymphatic system is well developed; and the course of the lymphatic vessels has been investigated with great care by various anatomists. The vessels themselves are thin, and have but few valves: they principally accompany the larger blood-vessels from all parts of the body to the aorta, around which they form a plexus, and ultimately join to give rise to two principal trunks or *thoracic ducts*: these terminate severally in the right and left jugular veins, and into these vessels the greater proportion of the lymph and chyle absorbed is of course poured, to be mixed with the circulating blood.

(2061.) Before describing the circulatory apparatus of Birds, it will be advisable in the next place to consider the nature and disposition of their organs of respiration, which, from what has been already stated concerning the heat and purity of the blood in these creatures, we are prepared to find presenting the highest possible condition of development. Birds, in fact, breathe not only with their lungs, but the vital element penetrates every part of the interior of their bodies, bathing the surfaces of their viscera and entering the very cavities of their bones; so that the blood is most extensively subjected to its influence. The lungs, in fact, are no longer closed bags as those of Reptiles are, but rather resemble spongy masses, of extreme vascularity, firmly bound down in contact with the dorsal aspect of the thorax,—their posterior surface being fixed to the ribs on each side of the vertebral column, and entering deeply into the intercostal spaces. Such lungs are obviously incapable of alternate dilatation and contraction; so that inspiration and expiration must be provided for by a mechanism specially adapted to the emergency. From an examination of fig. 360, the arrangement adopted will easily be understood. The bronchi derived from the bifurcated inferior extremity of the trachea plunge into the anterior face of

Fig. 360.



Inferior larynx and lungs of a bird.

the lungs (*c c*), and by innumerable canals distribute air throughout their spongoid substance; but the main trunks of the bronchial tubes, passing right through the pulmonary organs, open by wide mouths, represented in the figure, into the cavity of the thorax, into which the air likewise freely penetrates. The whole thoracico-abdominal cavity is moreover divided by septa of serous membrane into numerous intercommunicating cells, all of which are freely permeated by the atmospheric fluid, which in most instances is admitted into the very bones themselves, and even penetrates to the interspaces between the muscles of the neck and limbs, thus, in some birds of powerful flight, gaining free access to almost every part of the system.

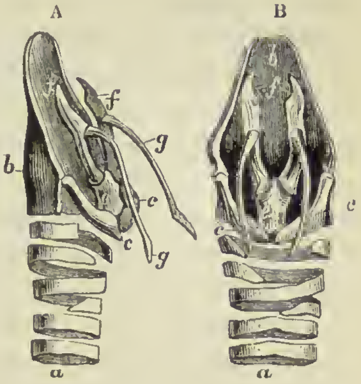
(2062.) The mechanism by which the air is drawn into, and then expelled from, this extended series of respiratory cells is sufficiently simple, the whole being accomplished by the movements of the expanded sternum, assisted slightly by the abdominal muscles. The descent of the sternum from the vertebral column necessarily enlarges the capacity of the chest, and, acting like a great bellows, sucks in air through the trachea, which not only fills all the spongy substance of the lungs, but penetrates to all parts whereunto air is admitted; while the ascent of the sternum, and consequent contraction of the thoracico-abdominal space, alternately effects its expulsion.

(2063.) The results obtained by this unusual arrangement are of great importance in the economy of the feathered races. In the first place, the perfect oxygenization of the blood is abundantly secured. Secondly, from the high temperature of the blood, the air drawn in becomes greatly rarefied, and thus materially diminishes the specific gravity of the bird. Thirdly, from the inflation of the whole body, the muscles, more especially those of flight, act with better leverage and firmer purchase; so that their efforts are materially favoured. And, lastly, it is owing to the capacity of the air-cells that the Singing Birds are enabled to prolong their notes to that extent which renders them pre-eminent among the vocalists of creation.

(2064.) In connexion, therefore, with the respiratory system of the feathered races, it will be advisable, in the next place, to consider the construction of the air-passages whereby the atmospheric fluid passes into and out of the body, and more especially of the organs of voice connected with them.

(2065.) The *trachea* is of very great proportionate length in correspondence with the elongated neck—commencing at the root of the tongue, and extending into the thoracic cavity, where it divides into two bronchial tubes, one appropriated to each lung (fig. 360, *l l*). The trachea of Birds is composed of cartilaginous rings, which are very generally ossified,—each ring, with the exception of two or three immediately beneath the upper larynx, forming a complete circle (fig. 361, A) surrounding the tracheal tube: these rings are enclosed between the soft membranes of the trachea, and thus keep the air-passages constantly permeable to the atmosphere.

Fig. 361.



Cartilages of the superior larynx of a bird.

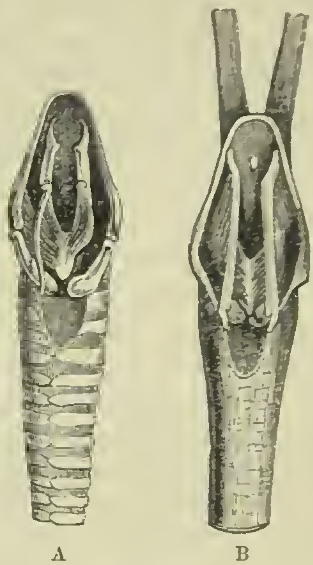
(2066.) In many birds, especially among the web-footed tribes, the trachea suddenly dilates into wide chambers or cavities of different forms and dimensions—a circumstance the object of which has not as yet been satisfactorily explained; and, what is still more inexplicable, in some genera, and those too with the longest necks, as, for example, the Wild Swan and many of the Wading birds, the lower part of the trachea is lengthened out and variously contorted before it terminates in the chest. This long trachea is provided with muscles whereby the rings may be approximated; and thus the length of the tube is considerably modified: these muscles (fig. 360, A, B, *h*) arise from the sternum, and sometimes also from the furcula, and are continued along the sides of the windpipe throughout its whole length.

(2067.) The upper larynx, or *rima glottidis*, is in Birds but of secondary importance in the production of vocal sounds: it is a simple fissure bounded by two osseous pieces (fig. 361, A, B, *f*), corresponding with the *arytenoid cartilages* of Mammalia; these, however, in the Bird are not connected with *chordæ vocales*, but simply, as they are separated or approximated, open or close the fissure of the glottis. When, therefore, we compare the framework of this organ with the cartilaginous pieces found in the larynx of Mammalia, considerable difference is perceptible, insomuch that it is not easy positively to recognize the analogous portions, more especially as in the Bird the cartilages are more or less completely ossified. If the broad anterior plate (fig. 361, *b*) be considered as the thyroid cartilage, we must suppose the cricoid to be represented by three distinct ossicles, two of which (*c c*) are lateral, while the third or central portion (*e*) supports the arytenoid bones (*f f*), which are moveably articulated with its anterior margin. The arytenoid bones themselves are of an elongated form, and each presents a long process (*g g*) for the insertion of the muscles that act upon them. These arytenoid bones are moved by two pairs of muscles—the superficial pair (*thyro-arytenoidei*) (fig. 362, B) serving to pull asunder, while the more deeply-seated (*constrictores glottidis*) (fig. 362, A) bring together the lips of the glottis.

(2068.) It is the lower larynx, situated at the opposite extremity of the trachea, at the point where that tube gives off the bronchi, that the real vocal apparatus of birds is situated; and in the more perfect Singing

Birds a very important set of muscles is appropriated to perform those delicate movements that regulate the condition of the air-passages at this part, and thus give rise to all the varieties of tone of which the voice is capable.

Fig. 362.



Muscles of the superior larynx of a bird.

(2069.) In the Insessorial Birds, by far the most accomplished songsters, five pairs of muscles are connected with the inferior larynx, and so disposed as to influence both the diameter and length of the bronchial tubes (fig. 360, A, B, *n*, *o*, *z*, *s*, *h*). In the Parrots, three pairs only are met with*; some of the Natatores have two; other Natatorial birds, as well as the Rasores and Grallatores, only one; and in a few, as the King of the Vultures and the Condor, the vocal muscles are quite deficient.

(2070.) Not only is the respiration of these highly-gifted Vertebrata thus abundantly provided for, but, as an immediate consequence of the necessity for supplying the system with pure and highly-oxygenized blood, the heart, hitherto but imperfectly divided, becomes now separated into two distinct sets of cavities, each composed of an auricle and of a strong ventricular chamber. The right side of the heart receives the vitiated blood from all parts of the system, which is poured into the corresponding auricle by three large veins, viz. one *inferior* and two *superior venæ cavæ*. The contraction of this auricle drives the blood into the right ventricle,—the auriculo-ventricular opening being guarded by a broad fleshy valve, formed by the muscular substance of the heart itself: and hence the venous blood is forced through all the ramifications of the pulmonary arteries.

(2071.) The aërated blood is then returned from the lungs by two veins, which pour it into the left auricle; and the left ventricle, now entirely appropriated to the systemic circulation, diffuses it through the body: thus, all mixture of the venous and arterial fluids being prevented, the system is supplied by the left side of the heart with pure and highly-vitalized blood.

(2072.) In the nervous system of Birds there is a very perceptible improvement when compared with that of Reptiles, more especially in the increased proportional development of the cerebral hemispheres: still, however, there are no convolutions seen upon the surface of the cerebrum, neither are those extensive communications between the lateral halves as yet developed which in the higher Mammalia assume such size and importance; the *corpus callosum* and *fornix* are both wanting, a simple commissure being still sufficient. Neither has the cerebellum in these animals assumed its complete development, presenting only the central portion; so that the *pons Varolii*, or the great commissure which in Man unites the lateral cerebellic lobes, is of course deficient. The olfactory and optic lobes are even here recognizable as distinct elements of the cerebral mass, and the origins of the nerves strictly conform to the arrangement already described in the brain of Reptiles. The rest of the cerebro-spinal axis presents no peculiarity worthy of special notice; and the general distribution of the cerebral and spinal nerves is so similar in all the Vertebrata, that it would be useless again to describe them in this place.

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* *Vide* Yarrell on the Organs of Voice in Birds (Linn. Trans. vol. xvi.).

(2073.) The *sympathetic* system in Birds is well developed, and its arrangement differs in no essential particular from what is seen in the human body: the situation of the cervical ganglia is, however, peculiar, inasmuch as they are lodged in the bony canal formed by the transverse processes of the vertebræ of the neck for the reception of the vertobral artery, and are thus securely protected, in spite of the unusual length and slenderness which the neck not unfrequently exhibits.

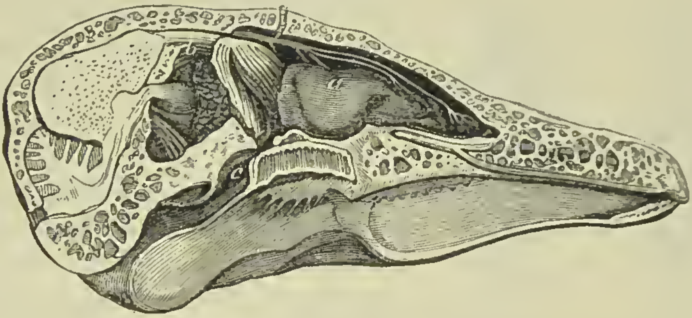
(2074.) But if in the general arrangement of the nervous system of the feathered races there is little to arrest our notice, we shall find in the construction of the organs of their senses many circumstances of considerable interest to the physiological reader; and consequently these will require a more extended description.

(2075.) The sense of touch must obviously be extremely imperfect in these animals: their body, enveloped in feathers, can be little sensible to impressions produced by the contact of external objects; and their limbs, covered as they are with plumes, or eased in horny scales, are but little adapted to exercise the sense in question. The beak alone offers itself as calculated to be a tactile instrument; but even this, enclosed as it is in the generality of birds by a dense corneous case, must be very inefficient in investigating the outward surfaces of substances; nevertheless in some tribes the beak is undoubtedly extremely sensitive, and is used to search for food in marshy soils, or to find it in the mud at the bottom of shallow waters. This is the case, for instance, in many of the long-billed Wading Birds, and also in the flat-billed aquatic families, such as the Goose and Swan; in these, in fact, the covering of the beak is comparatively soft, and the nerves that supply it, derived from the fifth pair, are of very considerable size.

(2076.) As we advance from the lower to tho more highly gifted races of the animal creation, taste is evidently one of tho last indulgences granted; and even in Birds it is only necessary to inspect the structure of the tongue in order to be convinced that they can derive but small enjoyment from this source. The skin of the tongue in these creatures is totally devoid of gustatory papillæ, and frequently, indeed, enveloped in a horny sheath; so that, if the sense of taste exists at all, it must be to the last degree limited and obtuse.

(2077.) In return, however, for the imperfection of the above senses, the olfactory apparatus in this class of animals begins to assume far greater importance than in the cold-blooded Vertebrata; and the nasal cavity indicates, by its extent, that it is now well adapted to investigate the odorous properties of the air taken in for respiration. The *septum narium* completely divides the nose into two lateral chambers of considerable extent, which individually communicate with the pharynx (fig. 363, *c*); and, upon the outer wall of each compartment, three convoluted laminæ, covered with a most delicate Schneiderian membrane, represent the turbinated bones of Mammalia, and increase the olfactory surface. Of these, the middle turbinated bone (fig. 363, *a*) is the largest; but the superior appears to be the most important, as it is upon this that the olfactory nerve is principally distributed, insomuch that Scarpa considered that the comparative powers of smell possessed by different birds might be estimated by the development of this portion of the olfactory organ. The olfactory nerves (fig. 363, *b*), as in Reptiles, still enter the nose without dividing, so that there is no cribriform plate to the ethmoid bone. The nostrils are simple apertures, perforating some part of the horny beak covering the upper mandible, and are never provided with moveable cartilages or muscles, as those of Mammalia will be found to be.

Fig. 363.

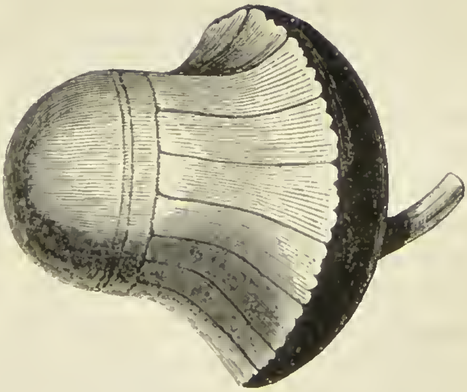


Olfactory apparatus in a Goose.

(2078.) The eye of a Bird is an optical instrument of such admirable construction, that, did not the nature of this work compel us to adopt the strictest brevity in our descriptions, it might well tempt us to indulge in lengthened details relative to the adaptation and uses of its various parts. If we contrast the Bird with the Reptile, or more especially with the Fish, and consider the totally different circumstances under which these animals exercise the sense of vision, we may well expect extraordinary modifications in the structure of their organs of sight. The Fish, immersed in a dense medium, can see but to a very limited distance around it; and the sphericity of the crystalline lens, with the consequent contracted antero-posterior diameter of the eyeball, at once testifies how small is the sphere of vision commanded by the finny tribes. The Bird, on the contrary, dwelling in the thin air, and not unfrequently soaring into regions where that air is still further rarefied, must survey a horizon even more extensive than that enjoyed by the terrestrial Mammal; while, from the rapid movements of the feathered races, it becomes absolutely requisite that the focus of the eye shall continually vary between the extremes of long- and short-sighted vision. The birds of prey, as they fan the air at an altitude which places them almost beyond the reach of human sight, or sail in broad gyrations through the sky, are scanning from that height the surface of the ground, and looking out for mice or other little animals on which to feed: but when the prey is seen, and the bird, shooting down with the rapidity of a thunderbolt, stoops upon the quarry, it must obviously be indispensable that it should see with as much clearness and distinctness when close to its victim, as it did when far remote; and to enable it to do this, special provisions have been made in the structure of the eyeball.

(2079.) A glance at fig. 365, exhibiting a section of the eye of an Owl, will show the anatomist that, in its general composition, the organ is similar to that of Man. The sclerotic and the choroid tunics present the same arrangement, the transparent humours of the eye occupy the same relative positions, and the iris and ciliary folds exist, as in the human subject. Descending from generalities, however, he will find many points in the organization of a bird's eye eminently deserving separate examination; and it is to these we would specially invite his notice. First, the shape of the eyeball is peculiar: it is not spherical, as in Man, nor flattened anteriorly, as in Fishes and aquatic Reptiles; but, on the contrary, the cornea is rendered extremely prominent, and the antero-posterior axis of the eye considerably lengthened. This is remarkably exemplified in the Owl, in which bird, as Dr. Macartney * pointed out, such is the disproportion between the anterior and posterior spheres of the eye, that the axis of the anterior portion is twice as great as that of

Fig. 364.



Eye of the Owl.

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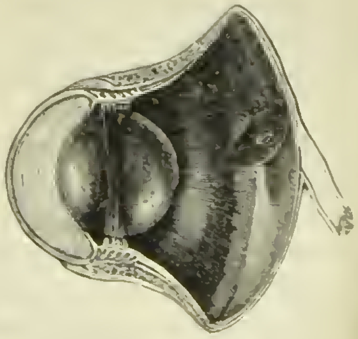
* Rees's Cyclopædia, art. BIRDS.

the other. The obvious consequence of this figure of the globe of the eye is to allow room for a greater proportion of aqueous fluid, and for the removal of the crystalline lens from the seat of sensation, and thus produce a greater convergence of the rays of light, by which the animal is enabled to discern the objects placed near it, and to see with a weaker light; and hence Owls, which require this sort of vision so much, possess the structure fitted to effect it in so remarkable a degree.

(2080.) But it is evident that, in order to retain this conical shape of the eyeball, some further mechanical arrangements are necessary, which in the spherical form of the human eye are not requisite. In Fishes, where the eyeball is constructed upon entirely opposite principles, being compressed anteriorly, cartilaginous supports are found imbedded in the sclerotic tunic, which in some cases is absolutely ossified into a bony cup. In many Reptiles the same end is obtained by placing a circle of bony plates around the cornea; and this latter plan is again adopted in Birds, to maintain their eyes in a shape precisely the converse of the former. In the Owls these ossicles are most largely developed; in such birds they form a broad zone (fig. 364), extending from the margin of the cornea, embracing the anterior conical portion of the eye, and imbedded between two fibrous layers of the sclerotic. The figure which is thus given to the eye, from the increased space obtained, is evidently calculated to allow the humours, forming the refracting media whereby the rays of light are brought to a focus upon the retina, to become materially changed in shape; and both the convexity of the cornea and the position of the lens may thus be altered so as to adjust them in correspondence with the distance at which an object is viewed. The cornea is rendered more convex, and the shape of the aqueous humour consequently adapted to examine objects close at hand, by the simple action of the muscles that move the eyeball: for these, seeing that the edges of the pieces composing the bony circle overlap each other so as to be slightly moveable, as they compress the globe of the eye, cause the protrusion of the aqueous humour, and the cornea becomes prominent; or if the bird surveys things that are remote, the cornea recedes and becomes flattened,—an effect caused by the recession of the aqueous humour, and, as some authors assert*, by muscular fibres disposed around the circumference of the cornea, and attached to its inner layer, which draw back the cornea in a manner analogous to the action of the muscles of the diaphragm upon its tendinous centre.

Fig. 365.



Section of the eye of an Owl.

(2081.) But the most beautiful

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* *Vide* Cyclop. of Anat. and Phys. p. 304.

piece of mechanism, if we may be pardoned the expression, met with in the eye of a Bird is destined to regulate the focal distance between the crystalline lens and the sentient surface of the retina, in order to ensure the clearest possible delineation either of near or distant objects. The provision for this purpose is peculiar to the class under our notice, and consists of a vascular organ, called the *marsupium* or *pecten*, which is lodged in the posterior part of the vitreous humour (fig. 365, *a*). This organ is composed of folds of a membrane resembling the choroid coat of the eye, and, being in like manner covered with pigment, might easily be mistaken for a process derived from that tunic, with which, in fact, it has no connexion, being attached to the optic nerve just at the point where it expands into the retina. Its substance seems to be made up of erectile tissue, and it is most copiously supplied with blood derived from an arterial plexus formed by the *arteria centralis retinæ* *; so that there is little doubt that, being like the iris endowed with an involuntary power of dilatation and contraction, as it enlarges from the injection of blood, it distends the chamber of the vitreous humour, and pushes forward the lens, while, as it again collapses, the crystalline is allowed to approach nearer to the retina; and thus the focus of the eye is adjusted upon the same principle as that of a telescope. Four *recti* and two *obliqui* muscles preside over the movements of the eyeball; but, as in the Reptilia, the *superior oblique* arises from the anterior part of the orbit, as well as the *obliquus inferior*, and its tendon is not reflected over a trochlea.

(2082.) Birds have three eyelids: an upper and a lower, resembling those of Mammalia; and a third, which, when unemployed, is concealed in the inner canthus of the eye, but can be drawn down vertically by muscles especially appropriated to its motions, so as to sweep over the entire cornea, which it then covers like a curtain.

(2083.) The upper and the lower eyelids differ but little in their structure from those of Man; nevertheless a few trivial circumstances are worthy of the notice of the student. In the first place, there are seldom any eyelashes attached to the palpebral margins; and secondly, the lower eyelid is the most moveable of the two, and not only contains a distinct arsal cartilage, but is provided with a special depressor muscle, which arises from the bottom of the orbit, like the *levator palpebræ superioris* of the human subject: the elevator of the upper eyelid and *orbicularis palpebrarum* are likewise well developed.

(2084.) The third eyelid, or *nictitating membrane*, is represented in fig. 366, A, *e* (the upper and lower eyelids having been divided through the middle, and turned back to display it): it is necessarily, to a certain extent, transparent; for birds sometimes look through it, as for instance when the Eagle looks at the sun †: it is therefore of a membranous texture, and a most admirable and peculiar muscular apparatus is given, by which its movements are effected. This is placed at the back of the eyeball, and may easily be displayed by turning aside the *recti* and *obliqui muscles*, as in fig. 366, B. Two muscles are then perceived arising from the globe of the eye, taking their origin from the outside of the sclerotic coat: one of these (*c*), named the *quadratus membranæ nictitantis,* arising from near the upper aspect of the eye, descends towards the optic nerve; but instead of being inserted into anything, as muscles usually are, it terminates in a most remarkable manner, ending in a tendinous sheath or pully, through which the tendon of the next muscle passes as it winds around the optic nerve. The second muscle (*d*), called the *pyramidalis memb. nictitantis,* arises from the inner aspect of the eyeball; and its fibres are collected into a long slender tendon, which, as it turns round the optic nerve, passes through the tendinous sheath formed by the *quadratus,* as a rope through a pully, and then is continued in a cellular sheath formed by the sclerotic, underneath the eye, to the lower angle of the third eyelid, into which it is inserted. The reader will at once perceive how beautifully these two muscles, acting simultaneously, cause the nictitating membrane to sweep over the cornea, which returns again into the inner canthus of the eye by its own elasticity.

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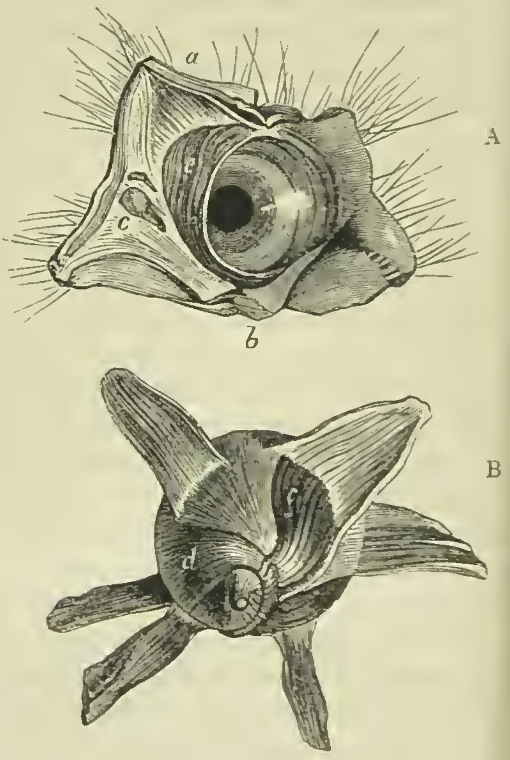
* *Vide* Barkow, in Meckel's Archiven, Band xii.

† Cuvier, Leçons d'Anat. Comp. tom. ii. p. 431.

Fig. 366.



Muscles of the nictitating membrane.

(2085.) Being thus provided with moveable eyelids, a lacrymal apparatus is, of course, indispensable; and accordingly, birds are supplied with two distinct glands, one being appropriated to the secretion of tears, while the other furnishes a lubricating fluid, apparently destined to facilitate the movements of the *membrana nictitans.*

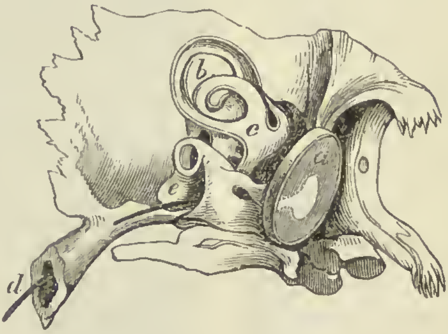
(2086.) The *lacrymal gland* is situated, as in Man, at the outer angle of the eye, and its duct pours the lacrymal secretion upon the eyeball near the external canthus. The *lacrymal canal,* whereby the tears, after moistening the cornea, are discharged into the nose, commences by two orifices (fig. 366, A, *c*) situated just behind the internal commissure of the eyelids, and is continued into the nasal cavity, where it terminates in front of the representative of the middle turbinated bone.

(2087.) The second gland, the *glandula Harderi*, seems to supply the place of the Meibomian glands of the human eyelids: it forms a considerable glandular mass, situated behind the conjunctiva, at the nasal angle of the eyelids; and through its excretory duct, which opens behind the nictitating membrane, the lubricating secretion that it furnishes is poured out.

(2088.) Besides the secreting organs above described, a third very large gland is found, generally lodged in a depression beneath the vault of the orbit, although in some genera it is situated external to that cavity: the secretion of this gland, however, is poured into the nose by one or more ducts, and thus serves copiously to moisten the Schneiderian membrane.

(2089.) The auditory apparatus of a Bird is almost precisely similar in its structure to that of one of the more perfect reptiles, such as the Crocodile. There is still no external ear, or osseous canal worthy of being called an external meatus: yet in a few rare instances, such as the Bustard, the feathers around the ear are so disposed as to collect faint impressions of sound; and in the Owls, besides possessing a broad opercular flap, that forms a kind of external ear, there are sinuosities, external to the *membrana tympani*, which resemble, not very distantly, those found in the ear of Man.

Fig. 367.

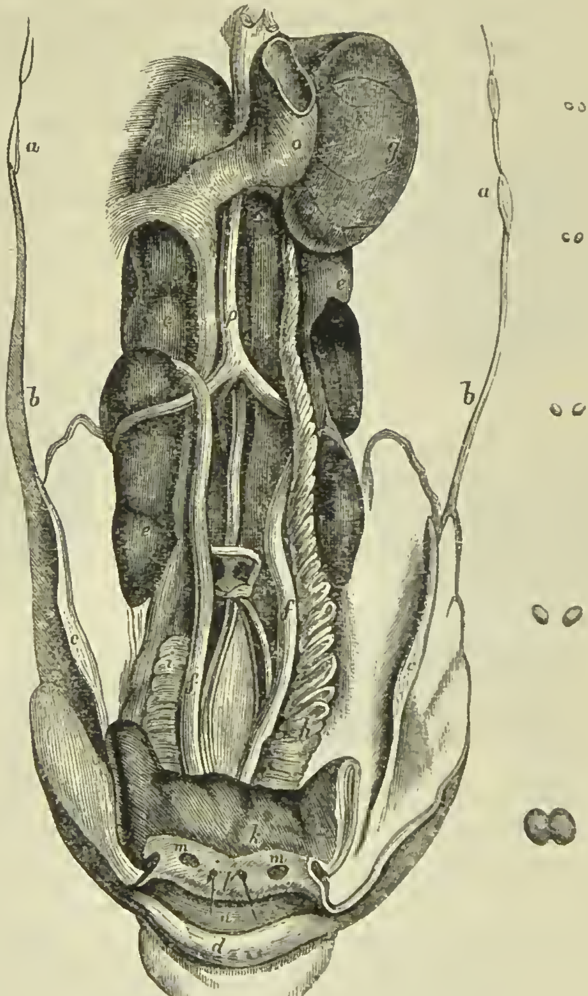


Organ of hearing in the Owl.

(2090.) Entering into the composition of the organ of hearing in the class before us, we have the *membrana tympani* (fig. 367, *a*), and tympanic cavity, from which a wide Eustachian tube (*d*) leads to the posterior nares. The labyrinth presents the *vestibule* (*c*), the *semicircular canals* (*b*), and the rudimentary *cochlea* (*e*); all of which so exactly correspond in structure with what has already been described when speaking of the ear of Reptiles (§ 1997 *et seqq.*), as to render repetition needless. A single trumpet-shaped bone, the representative of the stapes, communicates immediately between the *membrana tympani* and the *fenestra ovalis*; but two or three minute cartilaginous appendages, connected with the membranous drum of the ear, are regarded as being the rudiments of the *malleus*, *incus*, and *os orbiculare* met with in the next class.

(2091.) The *kidneys* in the Bird (fig. 368, *c c c*) are very large; they are lodged in deep depressions, situated on each side of the spine, in the lumbar and pelvic regions, their posterior aspects being moulded into all the cavities formed by the bones in that situation. In their essential structure each kidney is made up of innumerable microscopic flexuous tubes, which, joining again and again into larger and still larger trunks, ultimately terminate in the ureter, without the interposition of any infundibular cavity analogous to the pelvis of the human kidney.

Fig. 368.



Generative organs of the Cock.

(2092.) From the manner in which the kidneys are imbedded, the ureters are necessarily derived from their anterior aspect. After receiving all the terminations of the urinary tubules, they pass behind the rectum to the cloaca, into which they discharge the urinary secretion. The *cloaca*, therefore, receives the terminations of the rectum, of the ureters, and also, as we shall immediately see, of the sexual passages: no urinary bladder is as yet developed, nevertheless vestiges of its appearance begin to become visible. The cloaca is, in fact, in some birds divided into two compartments, distinct both in their appearance and in their office; these, moreover, are separated by a constriction, more or less well-defined in different species. It is into one of these compartments that the rectum opens, while the other (fig. 368, *m m*) contains the orifices of the ureters and generative canals; the latter is therefore generally distinguished by the name of the *urethro-sexual* portion of the cloaca, and is in truth a remnant of the allantois, and a rudiment of a bladder for the accumulation of the urine.

(2093.) An unctuous secretion, peculiar to the class under consideration, has been provided for the purpose of oiling the feathers; and in water-birds the fluid alluded to becomes of very great importance to their welfare, as it causes their plumy covering to repel moisture so efficiently that it is never wet. The gland given for this purpose is called the "*uropygium*," and is situated upon the back of the os coccygis; from this source the bird distributes the oily material thus afforded to all parts of its plumage.

(2094.) The male generative organs in Birds are fully as simple in their structure as those of the Reptilia. The testes are two oval bodies (fig. 368, *g*), invariably situated in the lumbar region, lying upon the anterior portion of the kidney. In their intimate structure they consist of contorted and extremely slender tubes, wherein the semen is elaborated, contained in a strong capsule. The sperm-secreting tubules of each testis terminate in a slightly flexuous *vas deferens* (*h*, *i*), that opens into the cloaca by a simple orifice (*m m*). In most birds it can scarcely be said that a penis exists at all, two simple rudimentary vascular papillæ at the termination of the *vasa deferentia* constituting the entire intromittent apparatus; so that copulation between the male and female must, in the generality of species, be effected by a simple juxtaposition of the sexual orifices: nevertheless in the web-footed tribes, which copulate in the water, and in the Ostrich, the penis of the male is much more perfectly organized, as will be seen by the following description extracted from Cuvier*.

(2095.) The structure of the penis is far from being the same in all birds provided with such an organ; it offers, in fact, two types extremely different from each other, whereof the Ostrich and Drake may be taken as examples. The penis of the Ostrich is of a size proportioned to that of the bird. Its form is conical; and a deep, narrow groove runs along its upper surface from the base to the point. The *vasa deferentia* open into the cloaca opposite to the commencement of the groove; so that the semen flows directly into this furrow. This penis consists, first, of two solid conical bodies, entirely composed of fibrous substance, supported at their base within the sphincter of the cloaca upon its inferior wall. The fibrous cones are placed side by side, but not confounded together; and the right is smaller than the left—no doubt to allow this organ, which never becomes soft as that of quadrupeds, to be more easily folded back into the cloaca. Secondly, of a fibro-vascular body, which constitutes the bulk of the inferior aspect of the penis, and is continued to its extremity. Thirdly, of a cellular portion, capable of erection, placed beneath the skin lining the urethral groove. This last is doubtless the first appearance of the *corpus spongiosum*, which in Mammifers completely encloses the canal of the urethra, while the two others represent the *corpus cavernosum*. The whole apparatus, when not in use, is drawn into the cloaca by two pairs of retractor muscles.

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* Leçons d'Anat. Comp. tom. v. p. 108.

(2096.) In Geese, Ducks, and many wading birds, such as the Stork, the structure of the male intromittent organ is totally different. When in a state of repose, it is lodged in a pouch under the extremity of the rectum, and curved, so as to describe three parts of a circle. When the penis is opened in this condition, it is found to be made up of two portions, each composing half of its substance. The parietes of one half are thick, elastic, and slightly glandular. The other presents internally a great number of transverse grooves and folds. This latter portion during erection unrolls itself outwards like a glove; and at the same time, the half first mentioned, introducing itself into the hollow cylinder formed by the second, fills it up, and constitutes the firmest part of the organ. Most of the grooves and folds visible during non-erection become much less apparent when the penis is protruded; and their direction being oblique, they prevent it from stretching out in a straight line, but oblige it to assume a corkscrew appearance. A deep groove runs along the whole length of this singular organ; and it is into the commencement of this groove that the *vasa deferentia* pour the seminal secretion.

(2097.) The females of species whose males possess a large penis are provided with a rudimentary *clitoris* of similar construction.

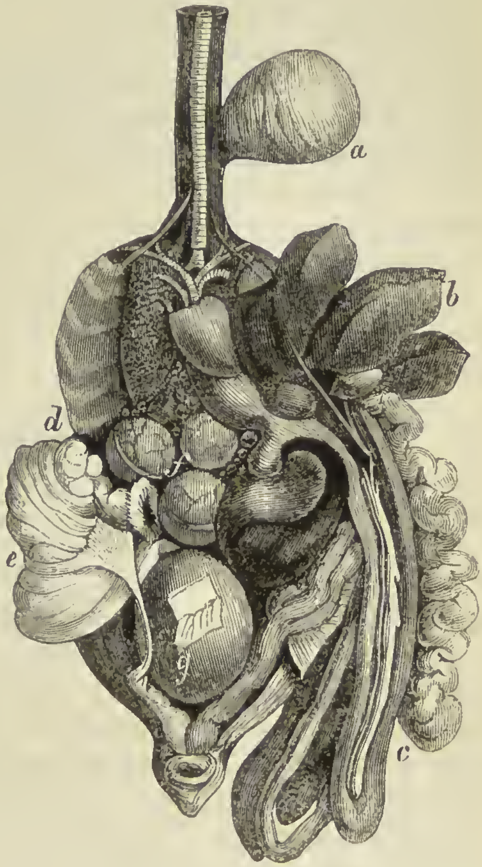
(2098.) The female generative system in the feathered tribes offers a remarkable exception to what we have as yet seen in the vertebrate Ovipara. Instead of being symmetrically developed upon the two sides of the body, the right oviduct, and most frequently the corresponding ovarium, remain permanently atrophied, and, although they do exist in a rudimentary condition, they never arrive at such dimensions as to allow them to assist in the reproductive process.

(2099.) The fertile ovarium presents in all essential circumstances the same organization as those of the Reptilia, and is in the same way attached by folds of peritoneum in the vicinity of the spine (fig. 369, *f*). The contained ova are found in all stages of maturity; and being connected together by narrow pedicles, the viscus assumes a distinctly racemose appearance.

(2100.) The oviduct (fig. 369, *d*, *e*) commences by a wide funnel-shaped aperture, and soon assumes the appearance of a convoluted intestine. Its lining membrane varies in texture in different parts: near the infundibular orifice it is thin and smooth; further down it becomes thicker and corrugated; and at last, near the termination of the canal, where the egg is completed by the calcification of its outward covering (*g*), it presents a villose texture. The oviduct ultimately opens into the corresponding side of the urethro-sexual compartment of the cloaca.

(2101.) We must in the next place proceed to describe, with as much brevity as is consistent with the importance of the subject, first, the nidus, or *ovisac*, in which the rudiment of the future being is produced; secondly, the structure of the germ (*ovulum*) when it escapes from the ovary; thirdly, the additions made to the *ovulum* as it passes through the oviduct; and lastly, the phenomena that take place during the development of the embryo by incubation.

Fig. 369.



Generative apparatus of the Hen.

(2102.) If the ovarium of a bird be examined whilst in functional activity, such of the pedunculated ovisacs (*calyces*, fig. 369, *f*) as have within them ovula ripe for exclusion will be found to consist of two membranes*. Of these, the exterior is very vascular, and is surrounded with a pale zone (*stigma*), occupying the centre of the calyx. The lining membrane of the ovisac, on the contrary, is thin and pellucid, but studded with minute corpuscles, which are probably glandular, or perhaps little plexuses of vessels. Within this ovisac the basis of the future egg (*ovulum*) is formed.

(2103.) The *ovulum* produced in the ovisac, when mature, is made up of the following parts. The bulk of it consists of an orange-coloured oleaginous material, enclosed in a most delicate and pellucid membrane

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* *Vide* Purkinje, Symbolæ ad ovi Avium historiam ante incubationem. 4to. Lipsiæ, 1830.

(*membrana vitelli*): this is the yelk of the future egg. Upon the surface of the yelk there is visible a slightly-elevated opaque spot (*cicatricula*), wherein is lodged the reproductive germ: this last, which is apparently the most important part of the ovulum, is a minute pellucid globule, and has been named, after its discoverer, the "*vesicle of Purkinje*," or the *germinal vesicle.*

(2104.) The phenomena attending conception are therefore simply these:—The membranes of the *ovisac* are gradually thinned by absorption; and being embraced and squeezed by the infundibular commencement of the oviduct, the transparent zone or stigma gives way, allowing the ovulum, covered only by its *membrana vitelli,* to escape into the oviductus. The rent ovisac is soon removed by absorption; and the *ovulum,* with its cicatricula, is left to be clothed with other investments: but the germinal vesicle is now no longer to be seen; its delicate covering having been, as Purkinje supposes, ruptured by the violence to which it has been subjected.

(2105.) It is during the passage of the ovulum through the canal of the oviduct that it becomes enclosed in the other parts entering into the composition of the egg: these are, the *albumen,* the *chalazæ,* the *membrana putaminis,* and the *calcareous shell.*

(2106.) The albumen, or glairy fluid forming the white of the egg. is secreted by the mucous membrane that lines the commencement of the oviduct; and being laid on, layer upon layer, gradually coats the *membrana vitelli.* Some of the albumen meanwhile becomes inspissated, so as to form an almost invisible membrane, the *chalazæ,* which, being twisted by the revolutions of the yelk, as it is pushed forward in the oviduct, is gathered into two delicate and spiral cords (fig. 371, *c c*), whereby the yelk is retained *in situ* after the egg is completed.

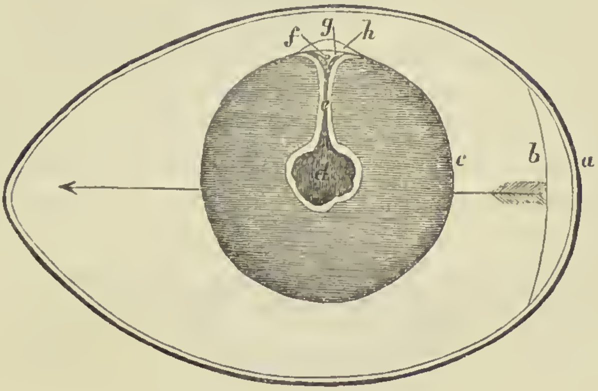
(2107.) The ovulum, now covered with a thick coating of albumen. and furnished with the chalazæ, at length approaches the terminal extremity of the oviduct, where a more tenacious material is poured out: it is here that the whole becomes encased in a dense membrane resembling very thin parchment, called "*membrana putaminis;*" and ultimately, on arriving in the last, dilated portion of the canal (fig. 369, *g*), the lining membrane of which secretes cretaceous matter, the *shell* is formed by tho gradual accumulation of extremely minute, polygonal calcareous particles, so disposed upon the surface of the egg that imperceptible interstices are left between them for the purpose of transpiration.

(2108.) Thus, as the oviduct is traced from its infundibular commencement, the different portions of it are seen successively to discharge the following functions:—the orifice of the infundibulum receives the ovulum from the ovisac; the succeeding portion, extending nearly three-fourths of its entiro length, secretes the albumen and the chalazæ; in the next tract it furnishes the *membrana putaminis;* and in the last place, the shell; after which, the complete egg is expelled through the cloaca.

(2109.) The anatomy of the egg prior to the commencement of incubation is therefore sufficiently simple. Immediately beneath the shell is the *membrana putaminis*; which, however, we must here remark, consists of two layers; and at the larger end of the egg these layers separate, leaving a space (fig. 370, *a*, *b*), called the *vesicula aëris*; we may further notice that the chamber so formed is filled with air containing an unusual proportion of oxygen, destined to serve for the respiration of the future embryo. Enclosed in the *membrana putaminis* the student next finds the albumen and chalazas (fig. 371, *c*); and lastly, the yelk, enclosed in its proper membrane (fig. 370, *c*), the *membrana vitelli.*

(2110.) We must dwell a little more at length, however, upon the composition of the yelk. The cicatricula (fig. 370, *g*) is made up of a thin membrane, which originally enclosed the vesicle of Purkinje (*f*); but this latter, although introduced into the diagram for the purpose of illustration, is in reality, as we have already seen, no longer visible; and we must now change the word *cicatricula* for that of *blastoderm*, which may be presumed to consist of the original cicatricula and the ruptured vesicle of Purkinje: it is from this *blastoderm*, or *germinal membrane*, as it is sometimes called, that the future being is developed.

Fig. 370.



Anatomy of the egg.

(2111.) Immediately over the blastoderm the *membrana vitelli* is slightly thickened (fig. 370, *h*); and beneath it is a canal (*e*), which leads to a chamber (*d*) placed in the centre of the yelk; this cavity is filled with a whitish granular substance.

(2112.) Such is the composition of the complete egg of a Fowl, and, with the exception of trifling circumstances hereafter to be noticed, of that of vertebrate animals in general. The development of the embryo is accomplished in the following manner.

(2113.) No sooner has incubation* commenced, than the blastoderm becomes distinctly separate from the yolk and the *membrana vitelli*, and, as it begins to spread, assumes the form of a central pellucid spot, surrounded by a broad dark ring (fig. 371, *g*, *h*); it at the same time becomes thickened and prominent, and is soon separable into three layers; of these, the exterior (fig. 372, c) is a serous layer; the internal, or that next the yolk (A), a mucous layer; and between the two is situated a vascular layer (B), in which vessels soon become apparent. These three layers are of the utmost importance, as from the first-mentioned all the serous structures, from the second all the mucous structure, and from the third the entire vascular system of the embryo originate.

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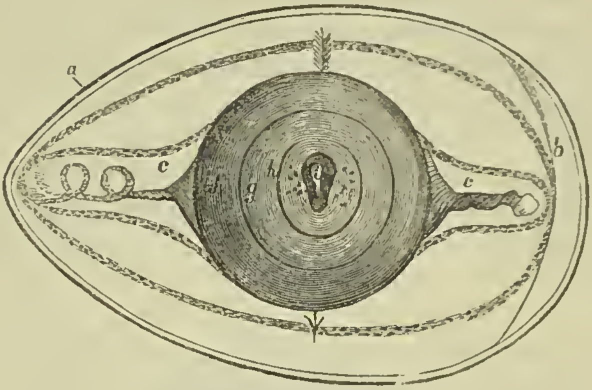
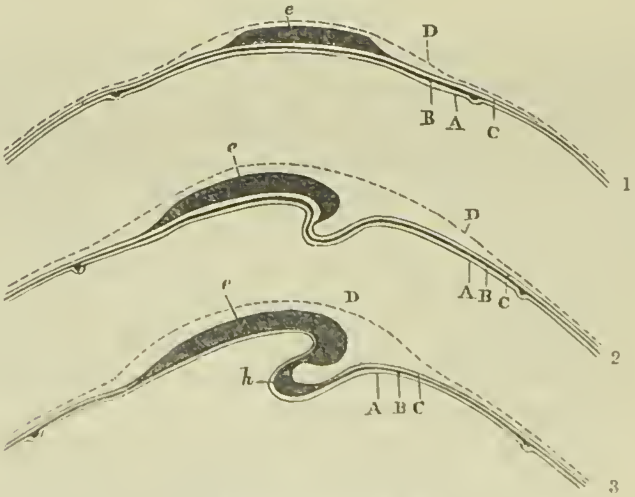
* Dr. Karl Ernst v. Baer, über Entwickelungsgeschichte der Thiere. Beobachtung und Reflexion. 4to. 1837.

Fig. 371.



Egg at commencement of incubation.

Fig. 372.



Earliest appearance of embryo.

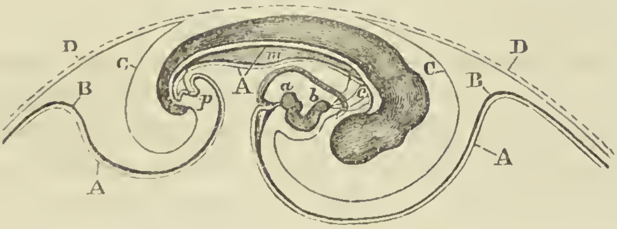
(2114.) Towards the close of the first day of incubation the blastoderm has already begun to change its appearance, and two white filaments are apparent in the middle of the central pellucid circle. Supposing a longitudinal section of it at this period, the *membrana vitelli* will be found to have become more prominent where it passes over the germinal space (fig. 372, 1, D). The outer layer of the blastoderm (C) has become thickened at *e* into the first rudiment of the dorsal portion of the embryo; but the mucous layer (A) and the vascular layer (B) have as yet undergone little alteration.

(2115.) At the commencement of the second day (fig. 372, 2), the anterior portion of the embryo is dilated, and bent down so as to inflect the three membranes of the blastoderm at this point.

(2116.) At the conclusion of the second day this inflection is carried still further, and from the vascular layer a single pulsating cavity (fig. 372, 3, *h*), the *punctum saliens* (the first appearance of a heart), has become developed; so that considerable advance is already made towards that disposition of the fœtus and its membranous investments represented in the next figure, to which we now beg the reader's attention.

(2117.) The serous membrane (fig. 372, C) has at the third day become reflected to a considerable distance over the back of the fœtus; at one extremity investing the head with a serous covering, while at the opposite it in like manner covers the tail: it is this reflection of the serous layer which forms the *amnion*, as will be observed in fig. 373, where the amniotic sac (C) is completed.

Fig. 373.



Embryo in a more advanced stage.

(2118.) The mucous layer (A) is now seen to line the as yet open space which is to form the abdominal cavity, and by its inflections gives birth to the rudiments of the abdominal viscera.

(2119.) From the vascular layer (B) has been developed the heart, now composed of two chambers (*a*, *b*), and the branchial arteries (*c*), which join to form the aorta (*m*), exactly as in the *Menopoma* (fig. 343). The *allantois* (*p*), the uses of which will be described hereafter, likewise begins to make its appearance*.

(2120.) At the fifth day (fig. 374) the lineaments of the viscera become tolerably distinct. The sac of the amnion (C) is completed; the liver (*i*) and the lungs (*e*) begin to show themselves; and the bag of the allantois (*p*) is largely developed; still, however, the heart (*a*, *b*) is that of a fish, and the aorta (*m*) formed by the union of the branchial arches (*c*); so we have yet to trace how, as the lungs increase in size, the circulatory apparatus becomes changed and the branchial organs obliterated.

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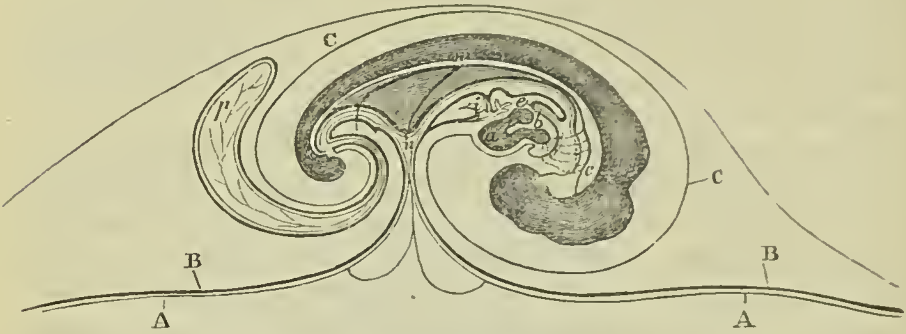
* Des Branchies et des Vaisseaux branchiaux dans les Embryons des Animaux vertébrés, par Prof. Ch. Ernst v. Baer (Ann. des Sci. Nat. tom. xv.).

Fig. 374.



Embryo about the fifth day of incubation.

(2121.) On the third day of incubation there exist four vascular arches (fig. 373, *c*) on each side, having a common origin from the bulb (*b*), which obviously represents the *bulbus arteriosus* of Fishes and Reptiles, before described; these encircle the neck, and join on arriving in the dorsal region to form the aorta, which commences by two roots, each made up of the union of the four branchial vessels of the corresponding side. The vascular arches are developed one after the other, the most anterior being visible even on the second day; shortly, a second appears behind the first, the former in the meantime becoming considerably larger; and at length the third and the fourth are formed, the fourth being still very small at the commencement of the third day.

(2122.) At this period three fissures are perceptible between the branchial arches, and in front of the first pair is the first appearance of the oral orifice,—which, however, is not, properly speaking, the aperture of the mouth, since at this epoch the jaws and buccal cavity are not as yet formed, but, physiologically considered, it rather represents the *pharynx*.

(2123.) At the close of the third day this branchial apparatus is already slightly changed: the branchial fissures are wider, and the fourth vascular arch is become nearly as large as the others. On the fourth day the first vascular arch is almost imperceptible, and that for two reasons: in the first place, it becomes covered up with cellular tissue; and secondly, it is so much diminished in size towards the second half of the fourth day, that it merely gives passage to a most slender stream of nearly colourless blood. By the close of the fourth day it is no longer recognizable, but, before its disappearance, it is seen to have given off from its most convex point a vessel, which becomes the *carotid* artery; so that, when the arch itself is atrophied, that portion of it which was connected with the bulb of the aorta becomes the trunk of the *carotid*.

(2124.) The second arch then becomes diminished in size, insomuch that the third and fourth receive the greater part of the blood, while in the meantime a fifth arch makes its appearance behind the fourth; so that in this way there are still four permeable arches.

(2125.) While these changes are going on in the vascular canals, the first branchial fissure gradually closes; and to make up for this, a new one is formed between the arch which originally was the fourth and that last developed.

(2126.) At the commencement of the fifth day there are consequently again four vascular arches and three branchial fissures on each side; but not the same as those of the third day, since one arch and one fissure have disappeared, and have been replaced by similar parts. During the fifth day, the vascular arch which at first was the second is obliterated, and the two succeeding ones become increased in size; but at the end of the fifth day all the branchial fissures are effaced, being filled up with cellular tissue, and no trace of them is left. The remainder of the metamorphosis seems to depend principally upon changes that occur in the *bulbus arteriosus* (fig. 373, *b*), which is by degrees converted into the bulb of the aorta. This part of the arterial system, from being a single cavity, about the fifth day divides into two canals, which become gradually more and more separated and bent upon themselves. The separation of the *bulbus arteriosus* into two vessels is, in the opinion of Professor Baer, owing to the circumstance that the ventricles gradually become separated by a septum, which, as it grows more complete, causes two distinct currents of blood to be propelled from the heart. The current coming from the right ventricle arrives sooner than the other at the vascular arches, and rushes through the two posterior and through the middle arch of the left side, while the gush of blood from the left ventricle fills the two anterior arches and the middle arch of the right side,—a circumstance depending on the course impressed upon the currents derived from the two ventricles. Each current becomes more and more distinct; and at last each is provided with a proper channel, forming the trunks of the *future* pulmonary artery and of the *future* aorta.

(2127.) It will be seen that as yet tho real aorta does not exist; for at this period of the metamorphosis all the blood passes through the vascular arches that remain into the dorsal vessel (fig. 374, *m*), which is formed in the same manner as the aorta of Fishes, by tho union of the branchial vessels.

(2128.) While the branchial fissures penetrated into the pharyngeal cavity, the branchial vessels were contained in tho corresponding branchial arches; but as soon as these fissures disappear, tho vascular trunks abandon the neighbourhood of the pharynx and begin to assume the character they afterwards present.

(2129.) The most posterior arch of the left side gradually disappears, and on the seventh day of incubation is no longer recognizable; whilst in tho meantime the current of blood from the right ventricle is directed in such a manner as to pass in front of this arch, and enters the posterior arch of the right side, and the last but one on the left.

(2130.) As, moreover, the two arches that were formerly the most anterior have become obliterated, while the third and fourth, on the contrary, are increased in size, the blood, passing backwards through these arches into the roots of the aorta, enters also the carotid artery, which now resembles a prolongation of the commencement of the aorta towards the head. Thus, one part of the primitive root of the aorta becomes the trunk of the carotid artery.

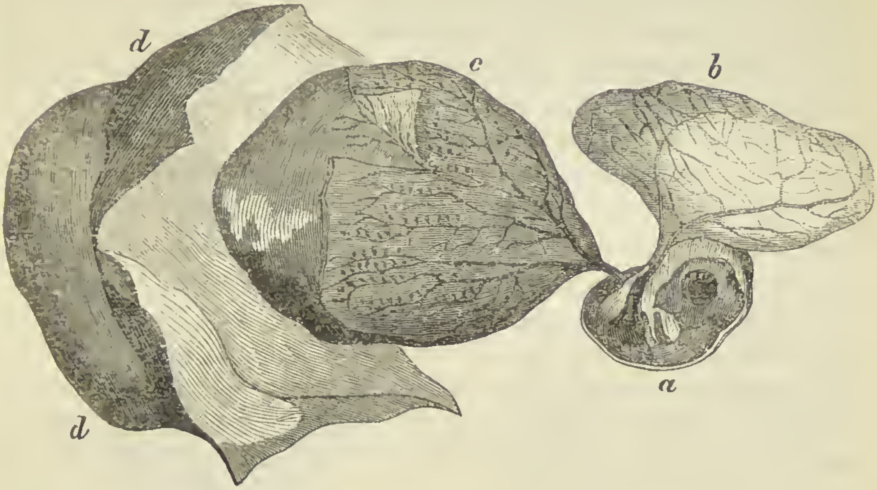
(2131.) There exist consequently, on the eighth day, three vascular arches on the right side, and only two on the left; and these five arches are derived from the heart, as are also two small vascular trunks, now quite distinct, which have been formed from the bulb.

(2132.) The anterior arch of both sides and the middle arch of the right side proceed from the left ventricle; the posterior arches issue from the right; but all of them as yet unite to form the two roots of the aorta, which are still of pretty equal size, and each root gives off a carotid artery. At the point where the anterior arches join the roots of the aorta, they are now seen to give off newly-formed trunks, which go to the anterior extremity of their respective sides; and as these limbs and the head increase in size and require more blood, the anterior arch propels a greater proportion of blood in that direction, and insensibly less and less into the aorta. The consequence is that the anterior arch becomes more and more decidedly the brachio-cephalic trunk; and, in short, on the thirteenth day it only communicates with the dorsal aorta by a small vessel, and ultimately becomes quite detached, forming the arteria innominata of the corresponding side.

(2133.) Meanwhile the posterior arches on both sides send out branches destined to the contiguous lungs. On the eighth day these vessels are still very small, and difficult to find; but they soon grow larger; and during the last half of the period of incubation, they show themselves as the immediate continuations of the arches from which they are derived,—their junctions with the aorta becoming more and more imperfect, and constituting the two *ductus arteriosi*. These canals are of very unequal size: that of the right side is much shorter than that of the left, which is now the only remnant of the original root of the aorta on that side, and considerably narrower than the root of the aorta on the right side. On the right side, in fact, the middle arch now becomes of great importance, and really constitutes the commencement of the descending aorta, receiving the other communications as subordinate parts.

(2134.) The bird having escaped from the egg, and having breathed for some time, all the blood from the right ventricle passes into the lungs, the ductus arteriosi become totally imperforate, and two distinct circulations are thus established—one proceeding from the right side of the heart through the lungs into the left side of the heart, the other from the left side of the heart through the system into the right side of the heart.

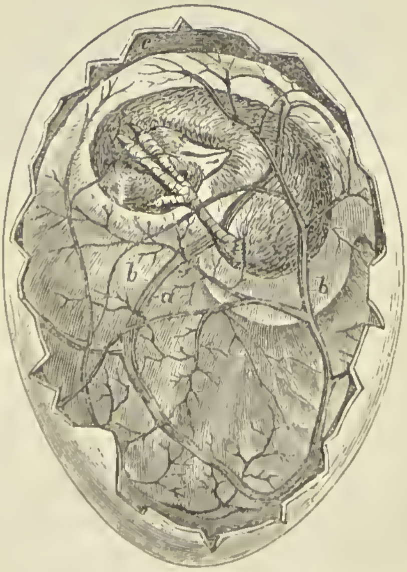
Fig. 375.



Membranes of the ovum.

(2135.) We see, therefore, that of the five pairs of vascular branchial arches which at first by their union formed the aorta as in Fishes, those of the first pair on both sides and of the fifth on the left side speedily disappear. The third on each side become the brachio-cephalic trunks, the fourth of the right side becomes the descending aorta, while the fifth of the right side and the fourth of the left side are converted into the pulmonary arteries. The very short trunk common to the two pulmonary arteries, as well as the equally short trunk of the aorta, properly so called, are produced by the transformation of the single cavity of the original "*bulbus arteriosus*" into two distinct canals, and thus this wonderful metamorphosis is accomplished.

Fig. 376.

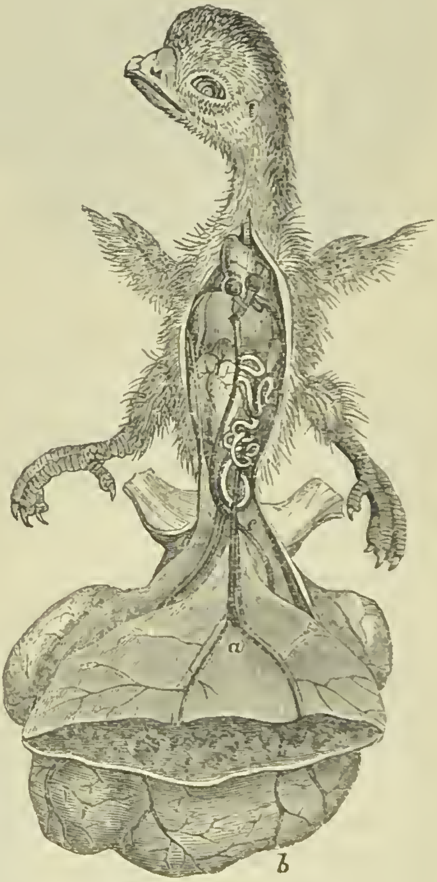


Membranes of the ovum *in situ*.

(2136.) About the one hundred-and-twentieth hour from the commencement of incubation, the vascular layer of the blastoderm has spread extensively over the yelk (fig. 375, *b*); and as the vessels formed by it become perfected, they are found to converge to the navel of the embryo, and to constitute a distinct system of arteries and veins (*omphalo-mesenteric*), communicating with the aorta and with the heart of the fœtus, and forming a vascular circle surrounding the yelk. The omphalo-mesenteric arteries (fig. 375, *b*, *c*), which thus ramify over the vitelline sac, are derived from the mesenteric arteries; and the blood distributed through them is returned, by the *omphalo-mesenteric veins*, to the superior vena cava of the young chick.

(2137.) As soon as the intestinal system of the embryo bird is distinctly formed, the membrane enclosing the yelk (*vitellicle*) is seen to communicate with the intestine by a wide duct (*ductus vitello-intestinalis*), whereby the nutritive substance of the yelk enters the alimentary canal to serve as food, and the mucous membrane lining the vitellicle becomes thrown into close wavy folds, so as to present a very extensive surface. Gradually, as growth advances, the yelk diminishes in size; and at length, before the young bird is hatched, the remains of it are entirely withdrawn into the abdominal cavity (figs. 378, 379), where its absorption is completed; but even in the adult bird, a little cæcal appendage, or *diverticulum*, still indicates the place formerly occupied by the *ductus vitello-intestinalis*.

Fig. 377.



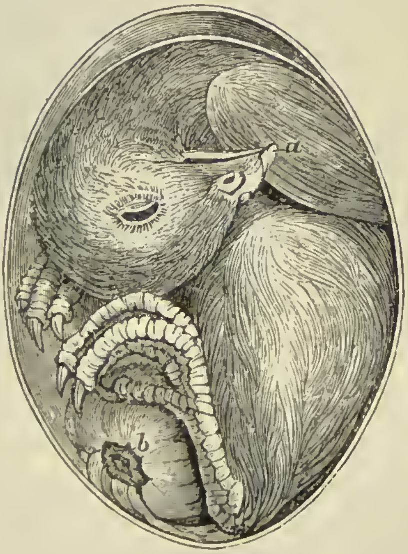
Vessels of the allantois.

(2138.) While the above phenomena are in progress, another important system of vessels, provided for the respiration of the bird *in ovo*, is developed, and obliterated before the egg is hatched.

(2139.) At about the period represented in fig. 374, the sides of the abdominal cavity, which is still open anteriorly, are occupied by transitory secreting organs, named *corpora Wolfiana*: these, apparently, are the rudiments of the genito-urinary system; and, to receive their secretion, a bladder is developed, called the *allantoid sac,*—a viscus which is moreover destined to play an important part in the economy of the embryo, and soon becomes its principal respiratory organ. The *allantois* first makes its appearance as a delicate bag (fig. 374, *p*), derived from the anterior surface of the rectum; but it expands rapidly, and soon occupies a very considerable portion of the interior of the egg (fig. 375, *c*), until at last it lines nearly the whole extent of the *membrana putaminis,* and becoming thus extensively exposed to the influence of the air that penetrates the egg-shell, it ultimately takes upon itself the respiratory function. When fully developed (fig. 376), it is covered with a rich network of arteries and veins (*a*, *b*) spread upon its surface. The arteries (fig. 377, *a*) are derived from the common iliac trunks of the embryo, and of course represent the umbilical arteries of the human fœtus; the vein enters the umbilicus, and, passing through the fissure of the liver, pours the blood, which it returns from the allantois in an arterialized condition, into the inferior cava, as does the umbilical vein of Mammalia.

(2140.) About the nineteenth day of incubation, the air-vessel at the large extremity of the egg (fig. 376, *c*) is ruptured, and the lungs begin to assume their function, by breathing the air that this vesicle contains. The circulation through the allantois then gradually diminishes, and it is slowly obliterated, until merely a ligamentous remnant, called the *urachus,* is left. In Reptiles, however, as we have already seen, a portion of the allantoid bag remains even in the adult creature (fig. 340, *q*); and in Birds, in that compartment of the cloaca in which the genital and urinary passages terminate, are vestiges of the same organ.

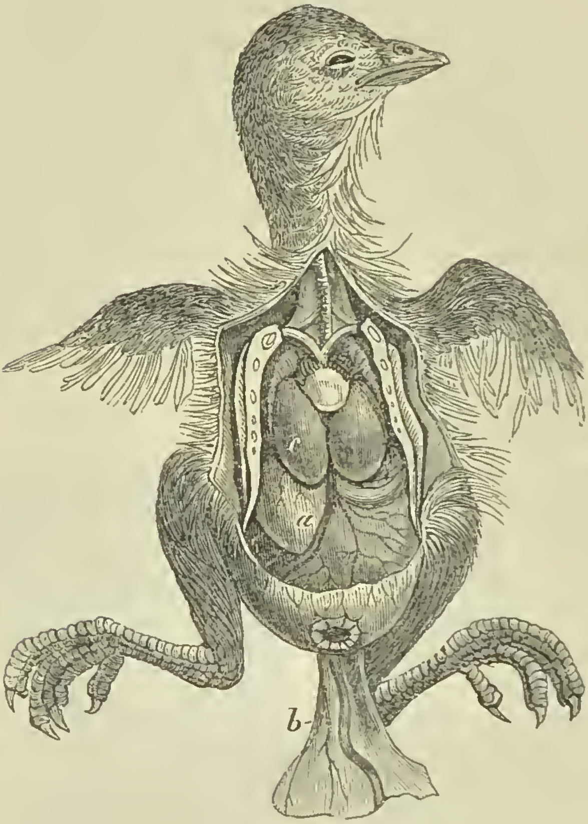
Fig. 378.



Position of the chick *in ovo.*

(2141.) Although the above description is intended to give a general view of the process of oviparous generation in its most perfect and consequently most complex form, the reader, in applying it to the development of the ovum in the inferior Ovipara, must bear in mind the following important differences:—1st, That in the air-breathing Reptilia the *white* of the egg is almost, if not entirely, wanting; but the other phenomena are similar to those witnessed in the Bird. 2ndly, That in Fishes not only is there no *white* formed, but, for obvious reasons, the allantoid apparatus is not developed. The egg in these lower tribes contains only the yelk and the cicatricula ; it swells from absorbing the surrounding water, and the fetus is developed upon the surface of the yelk,—the latter, which, as in Birds, communicates with the intestine, being slowly received into the abdominal cavity.

Fig. 379.



Viscera of mature chick.

(2142.) The subsequent changes that occur in the circulatory system of a bird, namely, the obliteration of the *foramen ovale* and of the *ductus arteriosi*, whereby the pulmonary and systemic circulations become quite distinct, are similar to those which take place in the Mammiferous fœtus, and will be described in the next chapter.

CHAPTER XXIX.

MAMMALIA.

(2143.) The highest boon conferred upon the lower animals, "Heaven's last, best gift," is parental affection. The cold-blooded Ovipara, unable in any manner to assist in the maturation of their offspring, were necessarily compelled to leave their eggs to be hatched by the agency of external circumstances; and their progeny, even from the moment of their birth, were abandoned to chance and to their own resources for a supply of nourishment. In Birds, the duties and the pleasures inseparable from the necessity of incubating their ova, and of providing nutriment for their callow brood, are indeed manifested to an extent unparalleled in the preceding orders of Vertebrata; but it is to the Mammalia alone, the most sagacious and intelligent of all the inhabitants of this world, that the Creator has permitted the full enjoyment of paternal and maternal love, has thrown the offspring absolutely helpless and dependent upon a mother's care and solicitude, and thus confers upon the parent the joys and comforts that a mother only knows—the dearest, purest, sweetest bestowed upon the animal creation.

(2144.) The grand circumstance whereby the entire class of beings generally designated under the name of Quadrupeds may be distinguished from all other members of the animal kingdom is, that the females of every species are furnished with mammary glands—secerning organs appointed to supply a secretion called *milk*, whereby the young are nourished from the moment of their birth until they have reached a sufficient age to enable them to live upon such animal or vegetable substances as are adapted to their maturer condition. The possession of these lactiferous glands would indeed be in itself a sufficiently decisive characteristic of the whole group; and if to this we add that their visceral cavity is separated into a thorax and abdomen by a muscular *diaphragm,* and that they breathe by means of lungs precisely similar to our own, we need not in this place dwell upon any more minute definition of the Mammiferous Vertebrata.

(2145.) The Mammalia, as we might be prepared to anticipate from their importance, are extensively distributed. The generality of them are terrestrial in their habits, either browsing the herbage from the ground, or, if of carnivorous propensities, leading a life of rapine by carrying on a bloodthirsty warfare against animals inferior to themselves in strength or ferocity. Many inhabit the trees; some burrow beneath the surface of the soil; a few can raise themselves into the air and flit about in search of insect prey; the Otter and the Seal persecute the fishes even in their own element; and the gigantic Whales, wallowing upon the surface of the sea, "tempest the ocean" in their fury.

(2146.) With habits so diverse, we may well expect corresponding diversity in their forms, or in the structure of their limbs; and, in fact, did we not compress our description of these particulars into reasonable limits, we might easily test the perseverance of the most patient reader in following us through the mass of details connected with this part of our subject. We shall therefore, commencing as we have hitherto done, with the osteology of the class, first describe, in general terms, the characters of a Mammiferous skeleton, and then, as we arrange the Mammalia under the various orders into which they have been distributed, speak of the most important aberrations from the given type.

(2147.) The vertebral column of all Mammals, with the remarkable exception of the Cetacea, is divisible into the same regions as in the human skeleton, viz. the cervical, dorsal, lumbar, sacral, and coccygeal or caudal portions.

(2148.) The cervical vertebræ are invariably seven in number. The Sloth (*Bradypus tridactylus*) was, until recently, regarded as forming a solitary exception, it having been supposed to possess nine cervical vertebræ; the researches of Professor Bell, however, show that even this animal conforms to the general law. The distinguished naturalist referred to has demonstrated *, "that the posterior two of these vertebræ have attached to them the rudiments of two pairs of ribs, in the form of small elongated bones articulated to their transverse processes; they must therefore be considered as truly dorsal vetebræ, modified into a cervical form and function suited to the peculiar wants of the animal." Professor Bell further observes that "the object of the increased number of vertebræ in the neck of the Sloth is evidently to allow of a more extensive rotation of the head; for, as each of the bones turns to a small extent upon the succeeding one, it is clear that the degree of rotation of the extreme point will be in proportion to the number of pieces in the whole series. When the habits of this extraordinary animal are considered, hanging as it does from the under surface of boughs, with the back downwards, it is obvious that the only means by which it could look towards the ground must be by rotation of the neck; and as it was necessary, to effect this without diminishing the firmness of the cervical portion of the vertebral column, to add certain moveable points to the number possessed by the rest of the class, the additional motion was acquired by modifying the two superior dorsal vertebræ, and giving them the office of cervical, rather than by infringing on a rule which is thus preserved entire without a single known exception."

(2149.) The occipital bone articulates with the atlas by two lateral condyles, instead of by a single central articulating surface,—a circumstance which depends upon the greatly-increased development of the encephalon, and the consequent expansion of the cranium.

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* Cyclop. of Anat. and Phys. art. EDENTATA.

(2150.) The number of dorsal vertebræ depends upon that of the ribs: thus in the Bat tribe there are only eleven; while in some of the Pachydermata (as, for example, in the Elephant and Tapir) as many as twenty dorsal vertebræ may be counted. The lumbar and sacral vertebræ will likewise be more or less numerous in different genera; and in the number of pieces composing the coccyx, or tail, there is every variety, from four to five-and-forty.

(2151.) The thorax is enclosed by ribs, which in structure, and in their mode of connexion with the dorsal vertebræ, resemble those of Man. At its dorsal extremity each rib is articulated by its head to the bodies of the vertebræ, and to the intervertebral substance; while its tubercle, or the representative of the second head of the rib of a Bird, is moveably connected with the corresponding vertebral transverse process. There are no sternal ribs; but these are represented by cartilaginous pieces, whereby, towards the anterior part of the thorax, each rib is attached to the side of the sternum: posteriorly, however, this connexion does not exist. The anterior ribs are therefore called *true ribs*, and the posterior, *false*, or *floating* ribs, precisely as in the human skeleton.

(2152.) The sternum is composed of several narrow pieces, placed in a line behind each other along the middle of the breast. These pieces are generally consolidated: by their lateral margins they give attachment anteriorly to the clavicles, if these bones be present, and, behind these, to the costal cartilages of tho true ribs.

(2153.) From the whole arrangement of the thorax, it is evident that the ribs are capable of extensive movements of elevation and depression, whereby the capacity of the whole thoracic cavity may be increased or diminished—movements which, aided by those of the diaphragm, draw in and expel the air used for respiration.

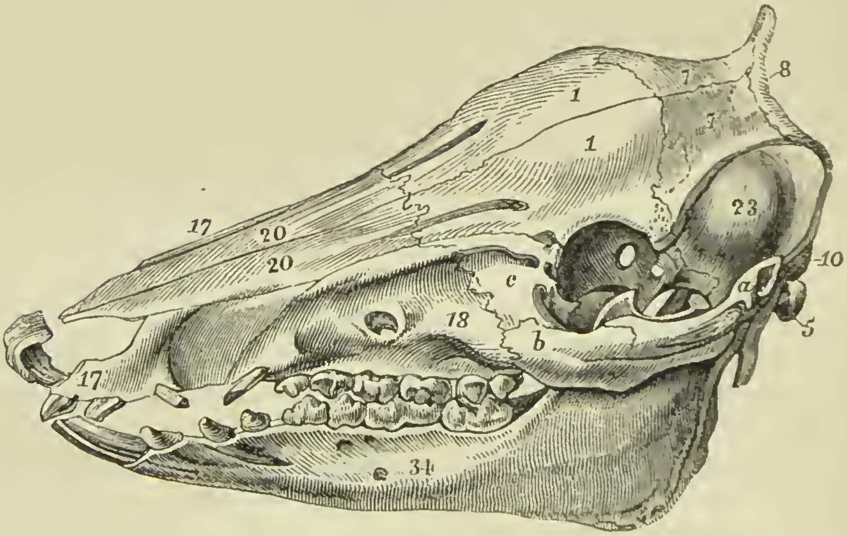
(2154.) The anterior extremity is appended to a broad scapula, generally unconnected with the rest of the skeleton, except by muscular attachments. In quadrupeds that use this extremity as an instrument of prehension or of flight, a clavicle is interposed between the scapula and the sternum; but most frequently this element of the shoulder is deficient, and even the coracoid bone, if a vestige of it remains at all, is reduced to a mere appendage to the scapula, known to the human anatomist as the coracoid process. The rest of the limb presents tho arm, the fore-arm, the carpus, metacarpus, and phalanges; but these aro so altered in appearance in different orders, that no general description will suffice, and we must therefore defer this part of our inquiry for the present.

(2155.) In the posterior extremity there is equal dissimilarity in the construction of the distal portions of the limb; but the pelvis, although much modified in form, consists of the same pieces as in the human subject, and in like manner has the pubic arch and foramina fully completed.

(2156.) The cranium and face are made up of numerous bones, easily recognizable, as they correspond in their general arrangement with those composing this part of the skeleton in the lower Vertebrata. Their development in the facial region is large, in proportion to the strength of the muscles moving the lower jaw; and they are so disposed as to form buttresses to resist the powerful pressure of the teeth, as well as to enclose cavities wherein are lodged the organs connected with the senses of smell and of vision. One example will answer our present purpose, and we have selected the skull of the Pig as one calculated to show a medium development of the whole series.

(2157.) In the face we find on each side two bones entering into the composition of the upper jaw, into which teeth are implanted; these are the *superior maxillary* (fig. 380, 18), and the *intermaxillary* (17). These bones, moreover, bound extensively the cavity of the nose, and, together with the palatine process of the *palate bone* (fig. 381, 22), constitute the bony palate, or roof of the mouth. The *nasal bones* (fig. 380, 20, 20) complete the upper part of the face; and, being in contact along the mesial line, arch over the nasal chamber.

Fig. 380.



Skull of the Pig.

(2158.) The orbit is bounded anteriorly by the *lacrymal bone* (*c*), and the *jugal* or *malar* bone (*b*). Its posterior boundary is generally wanting, as the external angular processes of the jugal and frontal bones do not meet.

(2159.) The orbital cavity is principally formed by processes derived from the os frontis, the sphenoid, the lacrymal, and the malar bone; the ethmoid and the palatine rarely entering into its composition.

(2160.) The *os ethmoides*, the *vomer*, and the *turbinated bones* will be described minutely when we speak of the olfactory apparatus, which they contribute to form.

(2161.) The *inferior maxilla* in Mammals is characterized by two circumstances, which distinguish it from that of other Vertebrata. It consists, in the first place, of only two lateral pieces, exactly similar to each other, joined together at the chin by a symphysis in many orders; but in others even this symphysis is obliterated at an early age, and in the adult the two lateral halves would seem to form but one piece.

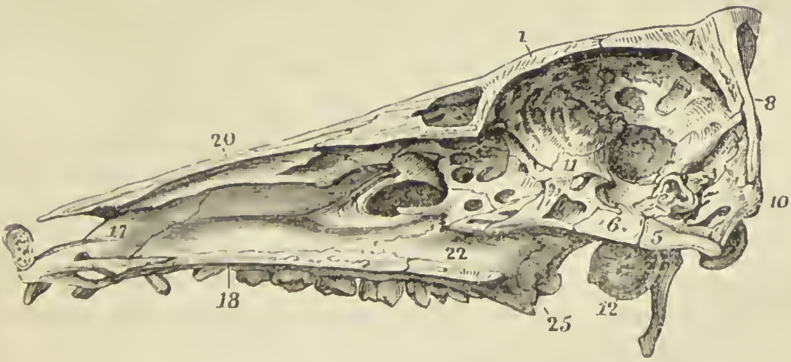
(2162.) Another character peculiar to the lower jaw of a Mammal is, that it is moveably articulated with the temporal bone by means of a convex and undivided condyle.

(2163.) These marks, identifying the mammiferous lower jaw, ought to be well remembered by the palæontologist.

(2164.) We shall hereafter have occasion to describe the teeth that arm the jaws of the different tribes of quadrupeds; and therefore we now proceed to examine their cranial cavity, and the bones that enter into its formation.

(2165.) The *frontal bones* (figs. 380, 381, 1, 1) are generally two in number; and even when, as in Man, they seem to form but one bone, the two lateral halves are produced from separate points of ossification, and only coalesce as age advances: sometimes, indeed, even in the adult, they remain permanently separated by suture.

Fig. 381.



Section of the skull of the Pig.

(2166.) The *parietal bones* (figs. 380, 381, 7, 7) occupy their usual position; and although generally double, as in the human skeleton, they are not unfrequently consolidated together, even at an early age, so as to represent but a single bone.

(2167.) The *occipital bone* consists primarily of the same pieces as in the Reptile; but in the Mammifer these are at an early period consolidated into one mass, situated at the back of the cranium. Its basilar portion (5) articulates with the atlas by two condyles; while the lateral wings (10) and the superior arch (8) surround the *foramen magnum*, and protect the cerebellic regions of the encephalon.

(2168.) The *sphenoid* (6), although composed of fewer separate pieces than in the Reptilia, and even regarded by the human anatomist as a single bone, is still distinctly divisible, especially in young animals, into two very important portions—one anterior, and the other posterior—each, as we shall soon see, forming the body of a distinct cranial vertebra. The posterior half (6) consists of the body, including the posterior clinoid processes, and of the greater alæ and pterygoid processes (fig. 381, 25). The anterior half is formed by the anterior clinoid processes and alæ minores (fig. 381, 11). These two halves may therefore be called, respectively, the *anterior* and *posterior sphenoids*.

(2169.) Lastly, we have the *temporal bone*, exhibiting but one piece, although made up of all the parts which in the Reptile were so obviously distinct elements. The petrous portion, wedged into the base of the cranium, still encloses the internal ear. The tympanic element (fig. 380, *a*) supports the membrana tympani. The mastoid process (fig. 381, 12) is the homologue of the mastoid bone of the Crocodile; and, lastly, the squamous element, with which the lower jaw is articulated (fig. 380, 23), in the Reptilia was visibly a distinct bone. Even to these may be added the zygomatic process, which Professor Owen regards as an independent elemental part.

(2170.) Reviewing, therefore, all that has been said relative to the composition of the skull in the different classes of Vertebrata, the following deductions may be arrived at *:—

1. That as we advance from lower to higher forms, the proportionate size of the cranium relative to that of the face becomes greater.

2. That the number of bones met with upon the inferior and lateral aspects of the head gradually diminishes: for in Mammalia the *pterygoid* and *tympanic* bones, which even in Birds are separate pieces, become very generally confounded with the *sphenoid* and the *temporal*: and also the petrous and squamous portions of the *temporal* become blended together.

3. The number of bones normally entering into the composition of the cranium of adult Mammalia varies considerably. When most numerous, there are twenty-eight—eleven in the cranium, and seventeen in the face. In this case the cranial bones are the following:—one occipital, one sphenoid, the two squamous portions of the temporal, the two tympano-petrous portions of the temporal, the two parietal, the two frontal, and the ethmoid.

(2171.) The bones of the face are: two superior maxillary, two intermaxillary, two nasal, two lacrymal, the vomer, two inferior turbinated bones, two palate bones, two jugal bones, and, lastly, the two halves of the lower jaw.

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* Meckel, Traité Générale d'Anatomie Comparée, tom. iii. 2de part., p. 195.

(2172.) It is true that some slight exceptions occur: thus, for example, in the Cetacea the pterygoid bones remain detached; in the Rodentia the occipital is divided into a superior and inferior portion; but in the latter, the two frontal and the two parietal become consolidated into one bone.

(2173.) In Man the bones of the cranium become much less numerous, inasmuch as all the elements of the *occipital*, of the *temporal*, of the *frontal*, the *intermaxillary*, and the *maxillary*, composing the upper jaw, and the two halves of the lower jaw, respectively coalesce; and the skull consists of but one-and-twenty bones,—seven in the cranium, and fourteen in the face.

(2174.) Even this number is not the smallest; for in some Monkeys the nasal bones unite and become consolidated into one piece.

(2175.) Having thus enumerated the different osseous pieces forming the crania of all classes of vertebrate animals, we must next consider them in another point of view, namely, as being continuations of the spinal chain of bones, or real vertebræ modified in form and proportions in conformity with the increased volume of the nervous masses they are destined to enclose. We must premise, however, that it is by no means our intention to adopt unreservedly the theoretical opinions of those Continental writers who find vertebral elements in the bones of the face, and even in the nasal cartilages; still, without overstraining the facts, it is easy to demonstrate very satisfactorily that the cranial pieces that immediately enclose the cerebral masses are strictly vertebræ, and present the same essential structure as those of the spinal region.

(2176.) That this is the case in the skull of a Reptile, no one, indeed, who examines the subject can hesitate to admit; but even in the Mammiferous cranium, where, from the enormous proportionate size of the encephalon, the cranium is most distorted, it is not difficult to perceive the relationship.

(2177.) The cranial vertebræ are three in number: the occipital, the parietal, and the frontal; these are exhibited in the subjoined diagram, after Carus, representing those of the Sheep.

(2178.) The occipital vertebra (fig. 382, A) has for its body the basilar portion; the arches bound the foramen magnum laterally; and above, the spinous process, flattened out and expanded in proportion to the size of those lobes of the brain and cerebellum which it defends, forms the posterior portion of the skull.

(2179.) The body of the second or parietal vertebra (B) is the body of the sphenoid—that is, more properly speaking, the posterior sphenoid bone, whose large alæ, curving upwards, meet the parietal, and thus an arch is formed of sufficient span to cover the middle lobes of the cerebrum.

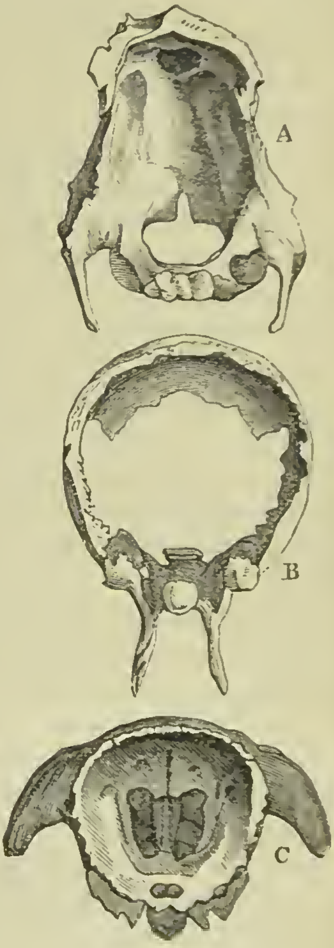
(2180.) The anterior, or frontal vertebra (c) has for its body the anterior sphenoid (*alæ minores*); its arch being completed by the cavity of the os frontis, which encloses anteriorly the cribriform plate of the ethmoid bone.

(2181.) From this analysis of the composition of the cranium, it is apparent that the temporal bones, although in Man they assist so materially in completing the cranial cavity, are only intercalated between the real vertebral elements; as indeed might almost have been anticipated, seeing how differently the pieces belonging to this bone are arranged in different classes of Vertebrata.

(2182.) Such is the general organization of the Mammiferous skeleton. Let us now proceed to consider the osteology of the different orders into which the Mammalia have been distributed, and observe in what respects they individually differ from each other.

(2183.) The transition from Birds to Quadrupeds, remotely separated as they might appear to be, is effected by gentle gradations of structure; and the MONOTREMATA, notwithstanding their quadrupedal form and hairy covering, are so nearly allied to the feathered Ovipara in many points of their organization, that they evidently form a connecting link between these two great classes of animals.

Fig. 382.



Cranial vertebræ.

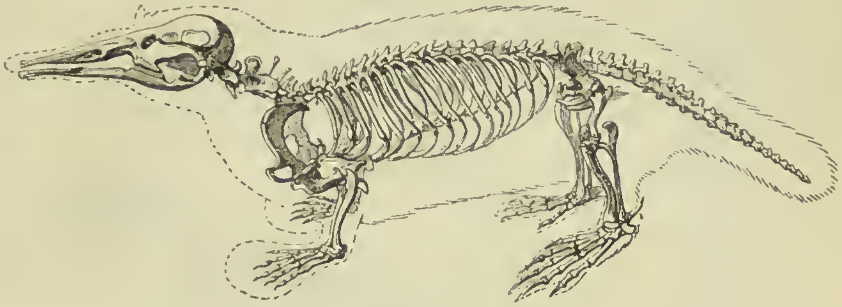
(2184.) It is true that they have mammary glands, and must therefore be supposed to give suck to their offspring; but it is not even yet satisfactorily determined whether they lay eggs, or produce living young. The structure of their generative apparatus would seem, in fact, to be rather allied to the Oviparous than the Mammiferous type; and, as in Birds, the rectum, the urinary passages, and the sexual organs, all discharge themselves into a common cloacal chamber; so that there is still but a single vent—a circumstance from which the name of the order is derived.

(2185.) Even their skeleton, in many points, presents a very close affinity to that of a Bird, as will be evident on examining the osseous system of the *Ornithorhynchus paradoxus* (fig. 383).

(2186.) The mouth of this quadruped, indeed, resembles that of a

Duck, whence the name of "Duck-bill," whereby it is usually distinguished. It has, moreover, a distinct *furcular bone* in addition to what

Fig. 383.



Skeleton of *Ornithorynchus paradoxus.*

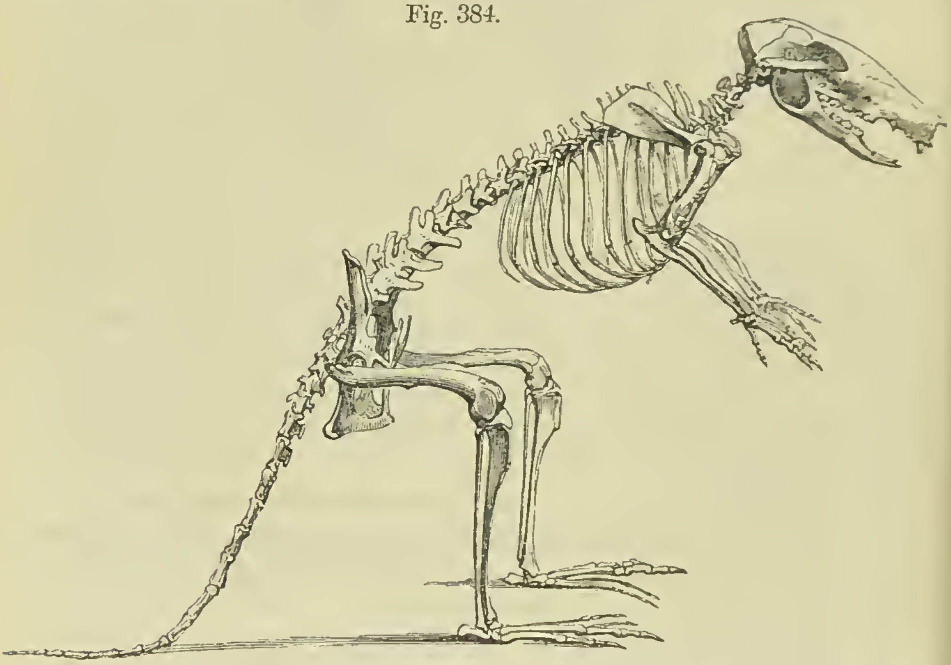
would seem to be the ordinary clavicles; but in reality these are the *coracoid bones* still largely developed. Moreover, the anterior or sternal ribs are ossified, and a spur is attached to the hind foot of the male, not remotely resembling that of a Cock: this last appendage is perforated by a duct, and has a gland connected with it, situated on the inner side of the thigh, by which a poisonous secretion was formerly supposed to be elaborated.

(2187.) The Marsupialia, it will be afterwards explained, as regards the conformation of their generative system, are organized in accordance with a type intermediate between that common to Birds and that which characterizes Mammalia properly so called.

(2188.) The Marsupial quadrupeds bring forth their young alive, but in such an imperfect condition, that at the period of their birth scarcely the rudiments of their limbs have become apparent; and in this state they are conveyed into a pouch formed by the skin of the female's abdomen, where they fix themselves by their mouths to the nipples of their mother, and, sucking milk, derive from this source the materials for their growth. These animals are peculiar to the Australian and American continents; nay, in Australia, so anomalous in all its productions, with one or two exceptions, and those perhaps brought there by accidental importation, all the quadrupeds are constructed after the Marsupial type. The great characteristic whereby to distinguish the skeleton of a Marsupial Mammifer is, the existence of two peculiar bones attached to the anterior margin of the pubis, which in the living animal are imbedded in the muscular walls of the abdomen, and thus support the pouch of the female. The marsupial bones, however, exist in the male likewise; and even in the Monotremata, that are evidently nearly allied to the proper Marsupialia, although no pouch is met with even in the female sex, the bones alluded to are found connected with the pubis.

(2189.) This great section of the Vertebrate creation, which perhaps ought rather to be regarded as a class by itself, is composed of numerous families, of diverse forms and very opposite habits. The Opossums (*Didelphys*) of the American continent live in trees, and devour birds, insects, or even fruits: in these, the thumb of the hind foot is opposable to the other fingers, and adapted for grasping the boughs, whence they are called *Pedimanes*; their tail is likewise prehensile. Others are terrestrial in their habits, wanting the prehensile thumb.

Fig. 384.



Skeleton of the Kangaroo Rat.

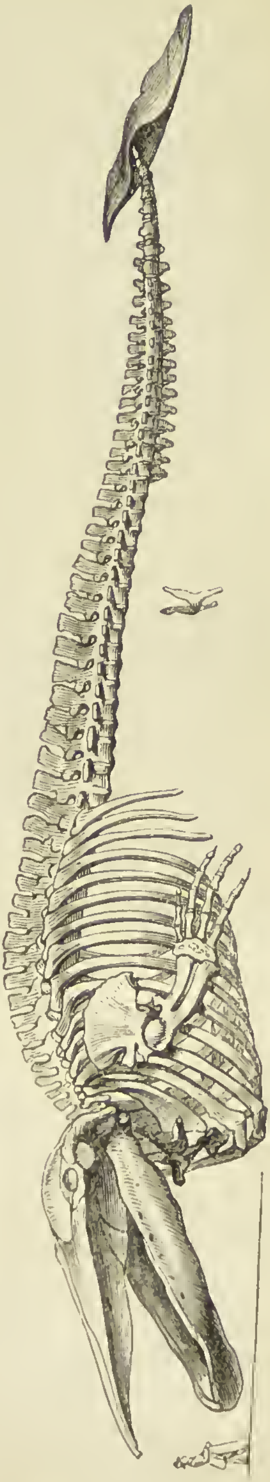
(2190.) The Kangaroo Rat, or Potoroo (*Hypsiprymnus*), of whose skeleton we have given a drawing (fig. 384), is remarkable for the disproportionate size of its hind legs: these, moreover, have no thumb. and the two innermost toes are joined together as far as the nails; so that there appear to be but three toes, the inner one being furnished with two claws. Such legs are well adapted to make strong and vigorous leaps over a level plain; and in the Kangaroos (*Macropus*) the extraordinary development of the posterior extremities is even yet more wonderful. In other respects, the skeletons of the Marsupialia conform to the general description already given.

(2191.) All other Mammiferous Vertebrata produce their young alive, and not until they have attained a considerably advanced state of development during their intra-uterine existence. The connexion between the maternal and fœtal systems in these orders is maintained during the latter periods of gestation by the development of a peculiar viscus, called the *placenta*; nevertheless, after birth, the young animals are still dependent upon the mother for support, and live upon the milk supplied by her mammary organs.

(2192.) The lowest order of PLACENTAL MAMMALIA comprises those forms which, although they breathe air by means of lungs, and have hot blood like ourselves, are appointed to inhabit the waters of the ocean, wherein they pass their lives, and even bring forth and suckle their young. In order to live under such circumstances as these, the CETACEA must necessarily, in many points of their structure, be organized after the model of fishes; and we cannot be surprised if, in their outward form, and even in the disposition of their limbs, they strikingly resemble the finny tribes. Their head is large—frequently, indeed, of enormous proportions; there is no neck apparent externally,—the head and trunk, as in fishes, appearing continuous. The anterior extremities are converted into broad fins, or paddles; whilst the pelvic extremities are absolutely wanting: posteriorly, the body tapers off towards the tail, and terminates in a broad, horizontal fin, which latter, however, is not supported by bony rays, as in the fish, but is entirely of a cartilaginous and fleshy structure. Frequently there is even a vertical dorsal fin; but this, too, is entirely soft and cartilaginous, so that in the skeleton no vestiges of it are apparent*.

(2193.) In the Whalebone-Whale (*Balæna mysticetus*) the peculiarities of the Cetaceous skeleton are well exhibited. In this gigantic animal (fig. 385), which sometimes measures upwards of a hundred feet from the snout to the tail, the head forms nearly a fourth part of the entire length of its stupendous carcass; so enormously developed are the bones of the face that form the upper and the lower jaws. The cranial cavity, wherein the brain is lodged, of course does not participate in this excessive

Fig. 385.



Skeleton of the Whalebone Whale.

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* It is interesting to see these fins still formed by the skin (*exoskeleton*), where the osseous system could not enter into their composition without deviating altogether from the Mammiferous type.

dilatation, but corresponds to the size of the brain lodged within it. It, however, presents one point of physiological interest, serving to prove still more demonstratively that the temporal bone is merely an adjunct to, and not essentially a constituent part of, the cranium; for here the petrous portion of the temporal bone, wherein is lodged the organ of hearing, is entirely detached from the skull, to which it is only fastened by a ligamentous connexion. This remarkable arrangement is, no doubt, intended to prevent the stunning noises that would else be conveyed from every side to the ear, by cutting off all immediate communication between the auditory apparatus and the osseous framework of the head.

(2194.) The cervical vertebræ, in conformity with the shortness of the neck, are exceedingly thin; and some of them are not unfrequently anchylosed into one piece.

(2195.) The thorax is composed in the ordinary manner; but the posterior ribs are only fixed to the transverse processes of the corresponding vertebræ. Behind the thorax the whole spine is flexible, its movements being untrammelled by any pelvic framework or posterior extremity; so that, as in fishes, the broadly-expanded tail is the great agent in locomotion; and from the horizontal position of this mighty oar it is better adapted to enable the animal to plunge headlong into the depth, and to rise again to the surface, with all expedition, than if it had been placed vertically, as it is in fishes.

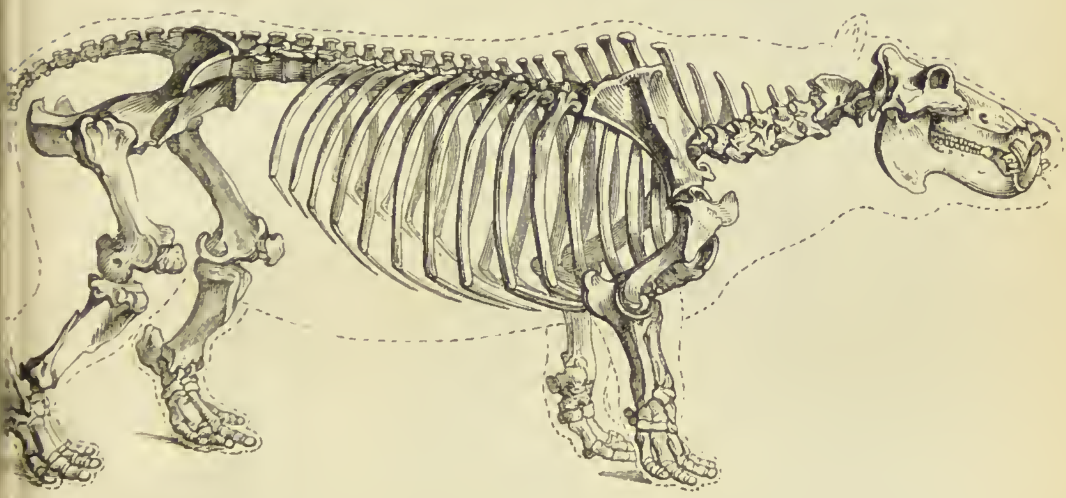
(2196.) The only vestiges of a pelvis met with in the Whale are, the rudimentary *ossa pubis* represented in the figure. These are imbedded in the abdominal muscles, and serve to support the external organs of generation: the caudal vetebræ, however, are distinguishable by the inferior spinous processes developed from their under surfaces. As to the construction of the anterior extremity, the shoulder is composed of the *scapula* alone. The arm and fore-arm are much stunted, and are not moveable at the elbow; therefore the muscles for pronating and supinating the arm do not exist, but are represented by aponeurotic expansions spread over the surfaces of the bones. The bones of the carpus are flattened, and more or less consolidated together. The fingers, likewise, are flat; and the whole limb so covered with tendinous bands, and enveloped in skin, as to form merely a fin whereby the creature guides its course through the water.

(2197.) In the Herbivorous Cetacea, as the Manatus and Dugong, the head is smaller in proportion to the sides of the body, and the hands better developed, so as to be useful in creeping on land, or in carrying their young. These genera inhabit the mouths of tropical rivers.

(2198.) The relationship between the Cetacea and the next order that offers itself to our notice is too evident not to be immediately appreciated. The thick and naked skin, the gigantic body, the massive bones, the bulky head, and even the variable and irregular teeth that arm the ponderous jaws are all again conspicuous in the PACHYDERMATA; and the river and the marsh, the localities frequented by the latter, as obviously indicate the intermediate position which these animals occupy between the aquatic and the terrestrial Mammalia.

(2199.) The skeleton of the Hippopotamus (fig. 386) offers a good example of the general disposition of the osseous system in the Pachydermata. The spinous processes of the last cervical and anterior dorsal vertebræ are necessarily of prodigious strength, giving origin as they do to the muscles that support the weighty skull; the ribs are numerous, broad, and flat; they extend nearly along the entire length of the trunk, and thus assist in sustaining the bulky viscera of the abdomen. The pelvis is massive, in proportion to the weight of the body; and both the thoracic and pelvic extremities, short, thick, and strong, form, as it were, pillars upon which the trunk is raised.

Fig. 386.



Skeleton of Hippopotamus.

(2200.) The most important differences observable between the various genera of Pachydermatous Mammalia are found in the structure of their feet, and in the number and disposition of their toes. In the Elephant there are five to each foot; but in the living state they are so encased in the callous skin which forms a sort of hoof to the foot of this monstrous animal, that they are scarcely perceptible externally. In the Hippopotamus, above delineated, there are four, and also in the Hog tribes; but in the latter the two middle toes are disproportionately large. The Rhinoceros has only three toes to each foot; and other varieties in this respect might easily be pointed out.

(2201.) In the SOLIDUNGULA, or SOLIPEDS, regarded by Cuvier as a family belonging to the order last mentioned, we have a tribe of animals quite peculiar as relates to the construction of their locomotive extremities.

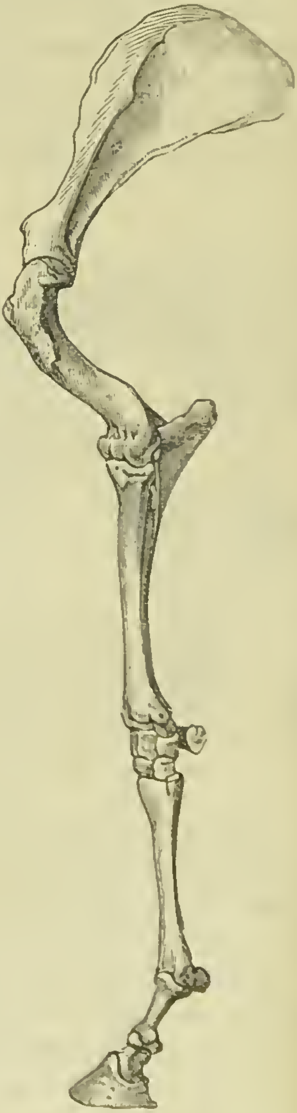
(2202.) In the Horse, for example (a creature obviously formed to be an assistant to the human race), so completely has every other consideration been sacrificed in order to ensure the utmost possible strength and solidity in the structure of the foot, that all the toes appear externally to have been solidified into one bony mass, which, being encased in a single dense and horny hoof, is not only strong enough to support the weight of the quadruped, and to sustain the shock produced by its most active and vigorous leaps, but becomes abundantly efficient to carry additional burdens, or to draw heavy loads in the service of mankind.

(2203.) In the anterior extremity of a Soliped (fig. 387) the shoulder consists only of the scapula, there being no clavicle to connect it with the sternum. The humerus is short and very strong: the radius and ulna are partially consolidated together, so that all movements of pronation and supination are impossible. The carpus is composed of seven short bones disposed in two rows. The metacarpus is a single bone (the *cannon bone*), which, from its length and size, is commonly called the "fore leg" of the horse, the carpo-metacarpal articulation being looked upon as the "knee." Lastly, the foot consists of three great phalanges; whereof the proximal is named the "*pastern*," the second the "*coronary*," and the distal phalanx the "*coffin bone*." In the macerated skeleton, however, the vestiges of two other toes are visible; but they are merely rudiments resembling osseous splints attached to each side of the metacarpus or cannon bone.

(2204.) In the posterior limbs of the Horse the same peculiarities are observable, in the construction both of the leg and foot.

(2205.) The RUMINANTIA constitute another order of quadrupeds of very great importance to mankind, distinguished by their remarkable habit of chewing the cud; that is, of bringing up the food again from the stomach into the mouth. for the purpose of undergoing a second process of mastication. They

Fig. 387.



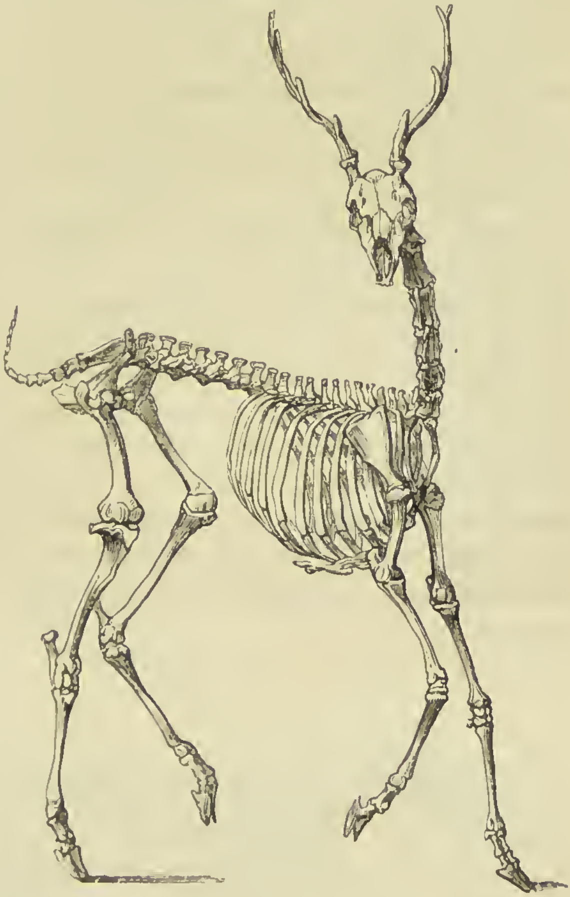
Fore leg of the Horse.

all have well-developed incisor teeth in the lower jaw, but none in the upper. The patient and thirst-enduring Camel, the stately Giraffe, the Ox, the Sheep, the Goat, the nimble Antelope, and the fleet and elegant Stag are all examples of this extensive order; but it is the skeleton of the last-mentioned alone that we shall select for delineation (fig. 388).

(2206.) The most remarkable feature observable in the Ruminant order of quadrupeds is, that, with the exception of the Camel tribe and the Musk-deer, the males, and sometimes the females, are provided with two horns attached to the os frontis, appendages not met with in any other Vertebrata. In some, as the Giraffe, these horns consist merely of a bony protuberance developed from each frontal bone, which is coated with a hairy skin derived from the common integument of the head. In others, as in the Ox, Goat, Antelope, &c., the bony nucleus of the horn is covered over with a sheath of corneous matter, giving it a hard and smooth surface.

(2207.) Both the above kinds of horns are persistent; but in the Deer tribe the defences of the head, which are large and branched, are deciduous, being formed every year from a vascular skin that covers them externally during the period of their growth, but shrivels up and dries when they are completed. These horns fall off after a certain time, to be renewed again the following season. The mode of their formation, however, will be examined in another place.

Fig. 388.

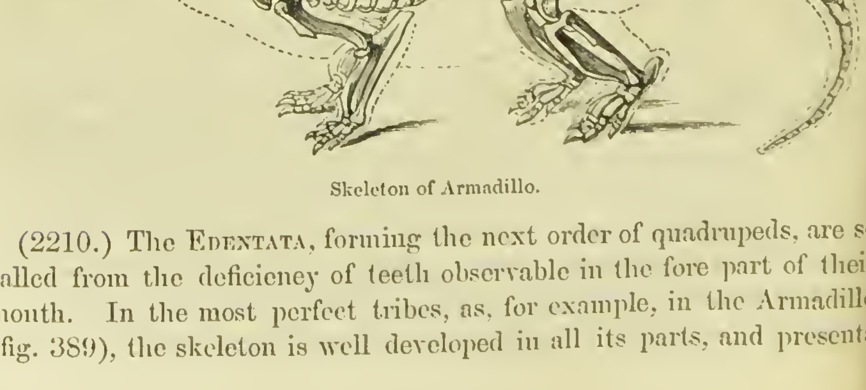


Skeleton of the Stag.

(2208.) In consequence of the weight of the horns in such species as possess weapons of this description, the head is necessarily extremely heavy; and in genera where the horns are wanting or feebly developed, as in the Camel or Giraffe, such is the length of the neck, that, even with a disproportionately small head attached to the extremity of so long a lever, incessant and violent muscular exertion would be needed to sustain or to raise it from the ground. This difficulty is obviated by a very simple and elegant contrivance: a broad band of ligament, composed of the same elastic tissue as that composing the *ligamenta subflava* of the human spine, is extended from the tips of the elongated spinous processes of the back, and sometimes even as far backwards as the lumbar and sacral regions. This ligament, strengthened by additions derived from most of the vertebral processes over which it passes, runs forward to be fixed anteriorly to the crest of the occipital bone, and to the most anterior of the cervical vertebræ. The whole weight of the cranium and neck being therefore fully counterbalanced by the elasticity of this suspensory ligament, the muscles of the neck act with every possible advantage, and all the movements of the head are effected with the utmost grace and facility.

(2209.) The Ruminantia are generally distinguished as having "cloven feet;" and in fact, both the hind and fore feet present a very characteristic formation. The bones of the fore-arms, as well as the *tibia* and *fibula*, are more or less completely consolidated, especially towards their distal extremities. The carpal and tarsal bones resemble those of the Horse, and are similarly situated. The metacarpal and metatarsal or cannon bones are respectively composed of two lateral halves united along the mesial line; and to each of these halves is attached a toe composed of three phalanges, the last phalanx of each being encased in a strong hoof. In some genera two rudimentary lateral toes are also distinctly recognizable; but these are too small to be used in locomotion.

Fig. 389.



Skeleton of Armadillo.

(2210.) The Edentata, forming the next order of quadrupeds, are so called from the deficiency of teeth observable in the fore part of their mouth. In the most perfect tribes, as, for example, in the Armadillo (fig. 389), the skeleton is well developed in all its parts, and presents nothing to attract our special notice, except, perhaps, the large proportionate size of the distal joints and claws that arm the toes; but in tho Sloths (*Bradypus*) so unusual is the conformation of the limbs, that it had at one time become quite the fashion for naturalists to bestow a passing expression of sympathy in alluding to these so-called miserable and imperfect members of the animal creation.

(2211.) "The Sloths," says Cuvier*, "derive their name from their excessive slowness, the result of a structure truly heteroclite, where Nature seems to have wished to amuse herself by producing something imperfect and grotesque. These animals have their fingers joined together by the skin, and only indicated externally by enormous compressed and hooked claws, which are bent when in repose towards the palms of the hands or the soles of the feet. The hind feet are articulated obliquely with the leg, and only rest upon their external edge: the phalanges of the fingers are articulated by tight hinge-joints, and the proximal ones become consolidated at a certain age with the bones of the metacarpus or metatarsus; even these last become anchylosed with each other for want of use. To this inconvenience in the organization of the extremities may be added one equally great, consequent upon their proportions: the arms and the fore-arms are much longer than the thighs and the legs; so that, when these creatures walk, they are obliged to drag themselves upon their elbows; their pelvis, too, is so wide, so much inclined laterally, that they cannot approximate their knees. Their deportment is the natural consequence of such disproportionate structure. They remain upon trees, and never quit one till they have stripped it of its leaves, so difficult is it for them to get to another; nay, it is even asserted that they let themselves fall from their branch to avoid the trouble of crawling down."

(2212.) Well may humanity pause before it ventures to accuse Nature of having "wished to amuse herself by producing something imperfect and grotesque;" and we should not have inflicted upon ourselves the task of quoting so painful a passage, did it not emanate from such a source, and had not ample opportunities of observation shown that the very structure so accurately described by Cuvier is better adapted than any other to the arboreal life for which the Sloth is destined. It is not upon the ground, but in the tree, that this animal must be criticised; and there, as we learn, among its native branches, hanging securely by means of its hooked toes and peculiarly-organized hind legs, it feeds in situations which otherwise would be left unoccupied; or, using its long arms, it swings from bough to bough, with a facility little to be expected from its appearance.

(2213.) The herbage that covers the plain, or the foliage of the trees, are not, however, the only vegetable materials that have been made available for the support of Mammiferous quadrupeds. The RODENTIA are furnished with teeth adapted to gnaw even the wood and the bark, or to crack nuts and other hard fruits, from which they derive nourishment.

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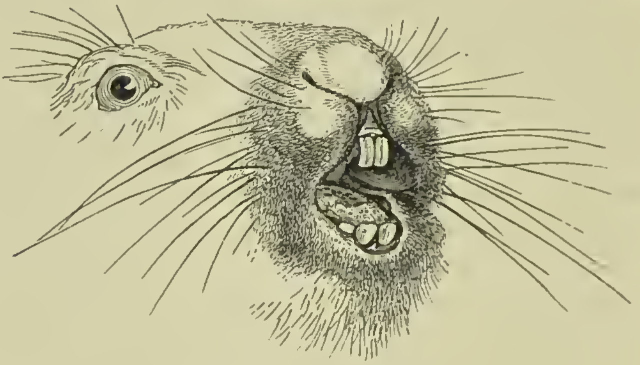
* Règne Animal, vol. i. p. 223 *et seq.*

(2214.) This order of Mammals, therefore, is distinguished by the possession of two incisor teeth in each jaw, so constructed as to erode hard substances, and which, moreover, by a peculiar mechanism, to be described in another place, are always kept sharp and trenchant: such are the incisor teeth of the Beaver or of the Hare (fig. 390).

Fig. 390.



Incisor teeth of the Hare.

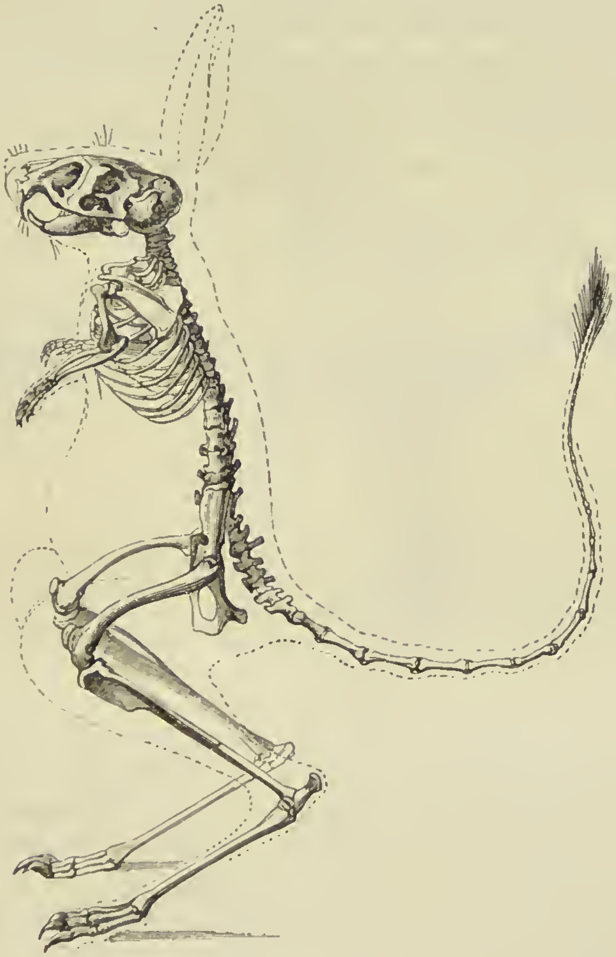
(2215.) The skeletons of the Rodentia are slight and feeble, adapted to the bird-like activity of their habits. Their fingers and toes are well developed, and the bones of the leg and fore-arm free throughout their whole length, although the movements of pronation and supination are as yet much limited. In many genera, more especially in such as climb trees like the Squirrels, the clavicles are very perfectly formed, so that the fore legs can be employed to a certain extent as hands, for conveying food to the mouth.

(2216.) Very generally the hind legs of the Rodentia are considerably longer than their anterior extremities: hence such genera run by bounds or leaps, and their course is extremely rapid. In the Jerboa (*Dipus*) (fig. 391) this disproportionate size of the hind legs is excessive. insomuch that the creature moves by leaps, like a Kangaroo; and the metatarsal bones of the three middle toes being consolidated into one bone, the whole limb resembles more that of a bird than of a quadruped.

(2217.) Among all the countless races of the animal kingdom, Man alone is permitted, in a state of nature, to arrive at old age; that is to say, at such an age as to allow feebleness and decrepitude to usurp the place of strength and activity. Man only is capable of such a privilege, because he alone possesses that foresight which enables him to prepare in youth against the decline of his faculties, and is endowed with sympathies and affections directing the strong and the vigorous to maintain the aged and the infirm.

(2218.) Among the lower animals, sickness and decay are not permitted to exist. Activity and health alone are conspicuous throughout the broad creation: disease and decline are banished from the world. Does any creature lack but for a brief period its accustomed powers of escape, the destroyer is at hand instantly to remove it from its appointed sphere of action. Butchers are placed on all sides, ready to perform their office; and nothing is permitted to live but what possesses its faculties and its strength unimpaired and unenfeebled.

Fig. 391.



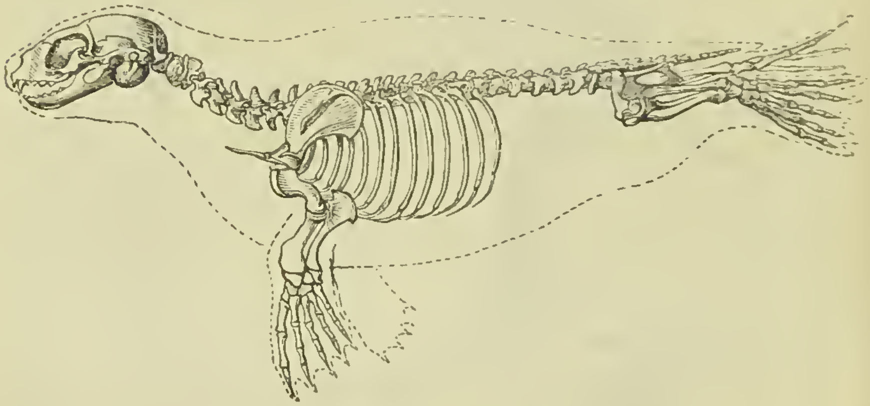
Skeleton of the Jerboa.

(2219.) The great character that distinguishes the Carnivorous quadrupeds is the high degree of intelligence and activity for which they are so remarkable. The perfection of their limbs and the acuteness of their senses at once indicate their superiority over the Herbivorous races; and their jaws, armed with powerful fangs, usually distinguished by the name of canine teeth, show at a glance the nature of their appointed food and their murderous propensities.

(2220.) The distribution of these tyrants of the animal creation we shall find to be coextensive with that of the victims they are appointed to destroy.

(2221.) The aquatic tribes of the Carnivora (*Amphibia*, Cuv.) are obviously constructed for swimming. Their bodies, covered over with short, close, and polished hair, taper off towards each extremity, resembling in form those of the Cetaceans. The cervical, thoracic, and lumbar regions of the spine are light and flexible; and the pelvis is contracted, and placed as far back as possible. Both the anterior and posterior extremities, although completely formed, are short, and in the living animal are only free externally as far as the carpal and tarsal joints. The feet, moreover, are broadly webbed, and thus become converted into most efficient paddles, by the aid of which these creatures swim with astonishing ease and elegance, the hinder pair performing at once the functions of oars and rudder. Upon land, however, their movements are, as might be supposed, extremely clumsy: it is true that they not unfrequently scramble on to the beach, there to bask in the sun, or to suckle their little ones; but if danger threatens, they immediately take to the water, and fall easy victims if their retreat towards the sea be intercepted.

Fig. 392.

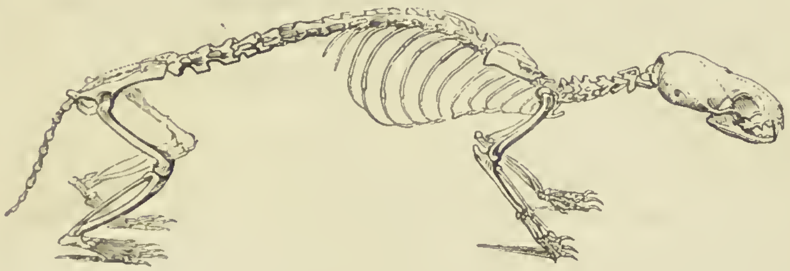


Skeleton of the Seal.

(2222.) Such being the helplessness of the Seals when they quit the water for the shore, it is not surprising that, in some of the larger and more unwieldy forms, assistant locomotive organs have been given, derived from unlooked-for sources. Thus in the Walrus (*Trichechus rosmarus*), which apparently obtains nourishment from the *fuci* of the shore, as well as by destroying living prey, even the canine teeth of the upper jaw are converted into instruments of progression, and serve as crutches to drag the animal along. In these creatures the upper jaw is extremely dilated and massive, and the canine teeth implanted in it not unfrequently project downwards to a distance of from one to two feet from the mouth. The strength of the tusks so formed is proportionate to the bulk of this gigantic Seal, and by their aid the Walrus is enabled to climb on to the rock in order to repose after its labours in the ocean.

(2223.) The Terrestrial Carnivora, that live upon flesh, are naturally divisible into two great sections. Of these, the most cruel and bloodthirsty, that walk only upon their toes, and are called from this circumstance "Digitigrada," bound along with an elasticity and swiftness that are abundantly provided for in the construction of every part of their osseous system. In this section are classed the extensive tribes of Weasels (fig. 393), Civets, Hyenas, and the race of Cats, the most formidable and ravenous of quadrupeds.

Fig. 393.



Skeleton of the Weasel.

(2224.) In the Feline Carnivora, indeed, to which belong the Lion and the Tiger, so justly celebrated for their strength and ferocity, a peculiar and beautiful provision is visible in the construction of the foot, whereby the claws that arm the last phalanges of the toes are kept constantly sharp, their points never being allowed to become worn by touching the ground; hence they are in these creatures terrific instruments of attack. The mechanism provided for effecting this is as follows:—three elastic ligaments, derived from the penultimate joint of the toe, are inserted into the last phalanx in such a manner that, by their elasticity, under ordinary circumstances, they keep the claw laid back upon the upper aspect of the foot; so that, the soft cushions beneath the toes being the only parts brought in contact with the ground, these creatures always walk with a stealthy and noiseless tread. But when the Tiger springs upon his prey, the tendons of the flexor muscle of the toes, implanted into the opposite surface of the phalanx, overcoming the elasticity of the retractile ligaments, pluck forward the curved claws, and burying them deeply in the flesh of the victim, the strongest animals struggle vainly to shake off a gripe so tenacious.

(2225.) But, among the Digitigrade Carnivora, none are of so much importance as the Dog—an animal specially provided for the use of man, to be his companion in the field, and his assistant at the chase.

Nor has Nature, in the case of the Dog, merely given to man a servant endowed with sagacity and zeal: man has need of help in various ways, and under very different circumstances. In bodily strength he is unable to cope with ferocious enemies that surround him on all sides; his senses are imperfect, when compared with those of some of the lower animals; in speed he is outstripped by the very creatures appointed to be his food: how then are all these deficiencies to be compensated? The Dog has been placed at man's disposal: its instincts, its size, its form, its senses, and its corporeal attributes are all subjugated to his control; and thus whatever aid he may require is to be obtained by the cultivation of its faculties.

(2226.) The PLANTIGRADE CARNIVORA, as their name indicates, in walking apply the entire sole of the foot to the ground, as far back as the end of the *os calcis*: such are the Bear (*Ursus*), the Glutton (*Gulo*), the Badger (*Meles*), and others of similar organization. These tribes are less exclusively carnivorous in their habits than the preceding; and their nails are not retractile, so that their points are blunted by dragging upon the ground.

(2227.) The INSECTIVORA form another section of these destructive quadrupeds, distinguished by their molar teeth being studded with sharp points, and thus calculated to devour insect prey: the Hedgehog (*Erinaceus*), the Shrew (*Sorex*), and the Mole (*Talpa*) are well-known examples of this division, and their habits are known to all. We need scarcely mention the peculiar circumstances under which the Mole passes its subterranean existence, or the extraordinary conformation of its anterior extremities, whereby they are converted into most efficient instruments for digging beneath the soil. The extended scapula, the strong and well-developed clavicle, the square and massive humerus, and, moreover, the broad and rake-like hand, all proclaim the office of this strange limb; while the long and carinated sternum indicates with equal plainness the size and power of those muscles by which the apparatus is wielded *.

(2228.) The CHEIROPTERA, or family of BATS, present a striking contrast to the Mole both in form and habits: neither would it be easy to conceive that a skeleton, consisting almost of precisely the same elements, could be converted to uses so diametrically opposite.

(2229.) In these Mammalia the anterior extremities are converted into wings, enabling them to emulate the very birds in their powers of flight, and in the velocity of their movements when upon the wing pursuing insect prey. In creatures destined to such a life, the whole skeleton must of course be lightened, and the bones attenuated to the utmost. The skull, the spine, the thorax, the pelvis, and the hind extremities, all testify, by the delicacy of their structure, that no unnecessary weight is here permitted. It is, however, in the construction of the anterior limbs that the Cheiroptera present the most remarkable peculiarities. The scapulæ are broad and expanded, covering a considerable portion of the back of the thorax, thus giving a firm basis to the wing. The clavicles are large and perfectly formed, in order to resist the powerful action of the pectoral muscles used in depressing the wings during flight; and in order to give those muscles a sufficient extent of origin, the sternum, although exhibiting the general characters of that of a quadruped, is deeply carinated along the mesial line. The humerus is of moderate length, but the fore-arm prolonged and slender; it consists, in fact, of but one bone, so that all movements of pronation and supination are necessarily impracticable. The carpal bones present their usual structure and arrangement at the base of the hand; but those of the metacarpus, excepting that of the thumb, are so extraordinarily lengthened, that they themselves form a considerable portion of the framework of the wing, which is completed by the phalanges of the fingers appended to their extremities. All these wire-like fingers are connected together by a broad duplicature of skin, derived from the sides of the body, which is continued along the whole length of the hind legs, and even fills up the interspace between these last and the tail: this membrane forms an expansion sufficiently extensive to become converted into an organ of flight. The fingers composing this strange hand are obviously incapable of closing towards the palm, as ours do when grasping an object: their only movements are such as fold up the wing against the side of the body, by laying the fingers close along the side of the fore-arm, as in closing a fan. The thumb alone is left free; and this being short, and armed with a strong nail, is employed in enabling the creature to cling to some elevated object in those gloomy lurking-places wherein it hides during the day.

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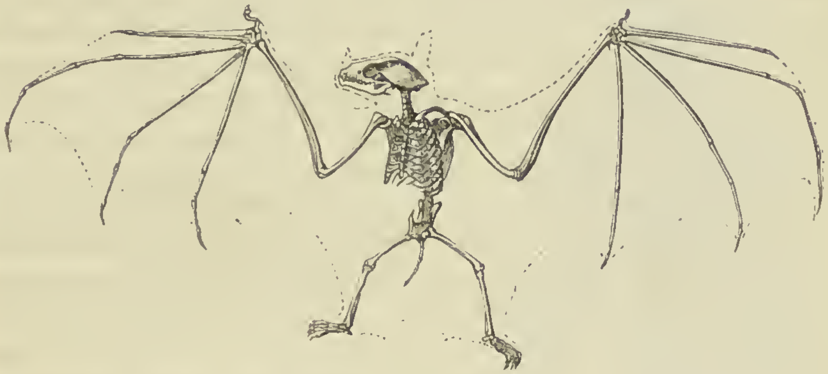
* For an admirable history of the habits of the Mole, the reader is referred to Bell's British Quadrupeds, page 85.

Fig. 394.



Skeleton of the Bat.

(2230.) The Quadrumana, next to mankind the most elevated members of the animal creation, are, as is evident from every point of their organization, the destined inhabitants of the trees; neither will it appear astonishing, when we consider the extensive provision that has been made for the support of animal life amid the dense and pathless forests of tropical climates, that animals so intelligent, and capable of enjoyment, should have been widely disseminated through extensive regions of our globe.

(2231.) The great distinction characteristic of the Quadrumana is found in the organization of their feet, all of which are converted into prehensile instruments, whereby they can seize the boughs of the trees wherein they reside, and thus securely swing themselves from branch to branch, or even leap from one tree to another, with wonderful activity and precision. Their hands are constructed upon the same principle as those of Man,—their thumbs, although less perfectly formed than our own, being opposable to the other fingers, and thus securing a firm and steady grasp. The bones of the fore-arm are free, and accurately articulated with each other; the pronation and supination of the hand are, therefore, accomplished with facility. In the construction of the feet the same provisions have been made to enable them to take a firm grasp: the toes, like the fingers of the hand, are long and flexible, and the representative of the great toe is converted into a very perfect thumb, easily opposable to the rest; the foot, or posterior hand, therefore, equals, or even surpasses, in its powers of prehension, the hand which terminates the anterior limb. For many of the American monkeys a fifth hand has been provided, formed by their long and muscular tail, which, from its extreme flexibility, can be forcibly twisted around any foreign object, and holds it with a tenacious grasp. Thus abundantly furnished with prehensile instruments, the Quadrumana are obviously most excellent and accomplished climbers, springing fearlessly through the forest by strong and vigorous leaps, or chasing their prey even to the topmost branches of the trees wherein they live.

(2232.) But however grotesquely some of the more anthropoid Quadrumana resemble the human race, the approximation, even in their outward form, is at best exceedingly remote. The lower tribes, such as the Lemurs of Madagascar, walk on all-fours like cats, and are still remarkable for their long and fox-like muzzle. The brutal and ferocious Baboons are scarcely more human in their appearance; and even in the most elevated species, called by the vulgar "Wild men of the woods," the interval that separates them from humanity is wide indeed!

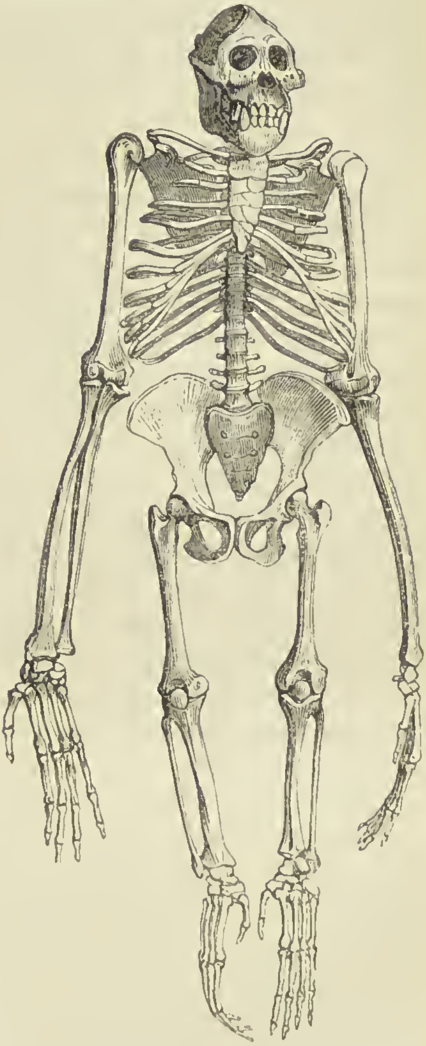
(2233.) Taking the skeleton of the Orang-Outang (*Simia Satyrus*) as one of the most perfect examples met with in the class under consideration, it is at once evident that such an animal is by no means adapted to walk in an erect position, although well fitted to maintain a semi-upright attitude, such as is best calculated for climbing. The skull, whose very outline indicates brutal ferocity, is armed with canine teeth scarcely less formidable than those of the Tiger; and the massive jaws of this creature are moved by muscles almost equally powerful. It is true that the protuberance of the face is considerably diminished, and the facial angle thus materially enlarged; but to make up for the feebleness of the upper jaw, consequent upon this reduced size of the bones composing it, additional strength is needed to resist the strong pressure of the enormous temporal muscles. This is given by adding strong buttresses to the outer angle of the orbit, formed by the union of the frontal and the jugal bones, and thus the whole outline of the face becomes more humanized.

(2234.) Another advance towards the condition of the human skull is apparent in the position of the *foramen magnum*, and of the condyles of the occipital bone, which are considerably advanced forwards beneath the base of the cranium, thus allowing the head to be articulated to the atlas at a very considerable angle with a line drawn through the axis of the spine,—a condition evidently favourable to the erect posture.

(2235.) The thorax is well formed and capacious, giving great freedom of respiration: but the spinal column is short and clumsy; neither does it present those graceful sigmoid curves that convert the human spine into a perfect spring, upon the top of which the head is carried.

(2236.) The arms are of inordinate length and extremely powerful, the joints perfect, and the clavicle well formed. But in the construction of the pelvic extremities the differences between this and the human skeleton become strikingly apparent. The pelvis is long, and the *ossa ilii* narrow; the thighs and legs so short, that, when the creature stands erect, the tips of the fingers almost touch the ground. The protuberance of the *os calcis* is very slight; and thus the posterior hands,

Fig. 395.



Skeleton of Orang-Outang.

although well adapted for taking hold of any object, are but ill calculated to sustain the weight of the body in an upright posture. Upon the ground, indeed, the living animal puts the spectator in mind of a human being crippled in the lower extremities; but in its native trees, these members, like those of the Sloth, are admirably suited to the circumstances under which the Orang is ordained to live.

(2237.) Having thus introduced the reader to the different orders of Mammalia, as well as to the principal differences observable in the arrangement of their osseous system, we must briefly glance at some few points connected with their myology, selecting those that seem most worthy of being specially pointed out to the notice of the anatomical student.

(2238.) To enumerate all the varieties that occur in the disposition of the muscular system in vertebrate animals would, of course, be incompatible with the extent of this work; and perhaps, even were it practicable, the details would scarcely possess much interest to the beginner in comparative anatomy. Considered generally, indeed, the muscular system of quadrupeds conforms very accurately in its arrangement to that of the human subject; and for the most part the same names are applicable to the individual muscles, allowance being made for such modifications in the manner of their origins and insertions as are rendered necessary by the disposition of the skeleton, or in order to accommodate them to the performance of special functions. To enumerate, therefore, the muscles of the jaws, of the neck, of the spine, of the chest, of the abdomen, or even of the extremities, in such genera as have the members last mentioned completely developed, would only be to repeat circumstances with which the human anatomist is already familiar; nevertheless there are some points of practical importance connected with this part of our subject that must not be altogether passed over in silence.

(2239.) The *diaphragm* is a muscle only met with in the class before us, and in all Mammalia it forms the great agent in respiration, dividing the thoracic from the abdominal cavity by a broad musculo-tendinous septum, and presenting a disposition in all essential particulars similar to that of Man.

(2240.) Another muscle of considerable anatomical interest is the cutaneous muscle provided for the movements of the integument. In many tribes, more especially those which, like the Hedgehog, the Echidna, and the Porcupine, have the skin covered with spines, this muscle is extremely developed, investing the greater part of the body with a thick layer of muscular fibres, called not improperly the *panniculus carnosus*. In Man, too, this muscle exists, but under a very different aspect, being only found in certain regions of the body, where it forms numerous cutaneous muscles adapted to different offices. In the neck, where it is principally developed, it is called the *platysma myoides*: in the facial region it is likewise of great importance,—the *occipito-frontalis,* the *corrugator supercilii,* and other muscles connected with the expression of the countenance, being indubitably but portions of the fleshy pannicle. In the palm of the hand it is slightly visible, forming the *palmaris brevis*; and even the little muscles connected with the external ear may be referred to the same series.

(2241.) In Whales, no pelvis or posterior extremities exist; it is needless, therefore, to remark that the whole of the muscular system appropriated to those parts in higher animals must be totally wanting; but, in return, the muscles connected with the caudal portion of the spine are amazingly powerful, so as to render the horizontally-expanded tail an instrument of propulsion adequate to the necessities of these unwieldy animals. A large triangular muscle is found in the CETACEA, apparently replacing the *quadratus lumborum,* the *psoas,* and the *iliacus,* which arises from the lower surface of the last rib, from the last dorsal vertebra, and also from those of the loins and sacrum: from this powerful assemblage of muscular fasciculi, tendons are given off, to be inserted into the lower surface of the bones that support the tail, converting this organ into a mighty oar, adapted by its position to bring the creature with all speed to the top of the ocean in search of air. It is, as might be supposed, in the muscles of the limbs that the most important differences exist. In the anterior extremities, for example, the presence or absence of a clavicle will materially affect the disposition of the muscles of the shoulder, as will also the existence of a coracoid process to the scapula; nevertheless in their general arrangement they conform to those of Man. The *rhomboid* muscles, which to creatures walking on all-fours must be important agents, are generally found in quadrupeds to take their origin as far forward as the head: the *serrati magni,* likewise, whereby in the prone position the weight of the body is as it were suspended from the scapula, must be immensely strong.

(2242.) The muscles acting upon the arm are similar in all the Mammalia; but in the fore-arm, as might be expected from the very variable condition of this part of the skeleton, the disposition of the muscular system varies too, and even the existence of many muscles could not be expected: thus as the movements of pronation and supination are, from the immoveable condition of the bones of the fore-arm, impracticable in the CETACEANS, the RUMINANTS, the SOLIPEDS, and others, the *pronators* and *supinators* are denied; or, if their representatives exist, they become simply assistants in flexion and extension. The flexors and extensors of the wrist are pretty constant; but the muscles devoted to the hand and fingers vary in almost every order. The *palmaris longus,* although generally present where the hand is flexible, is wanting where its action upon the palmar fascia would be useless, as for example in the Ungulate tribes.

(2243.) In quadrupeds there are two extensor tendons appropriated to each of the fingers that correspond to the four outer fingers of the human hand, whilst in Man the index and little fingers only have auxiliary extensors.

(2244.) The abductor and extensor muscles of the thumb are not so perfectly developed in any animals as they are in the human hand. The *short extensor,* in fact, is wanting even in Monkeys; and in the lower orders of quadrupeds even the *extensor longus* and *abductor* are blended together, or totally wanting.

(2245.) The *deep and superficial flexors* of the fingers are very generally met with, the number of tendons furnished by each corresponding of course to that of the fingers themselves; but in the Solipeds the two muscles are almost blended together. Even in the Ruminants, although these muscles remain separate, their tendons become confounded together, and divide again, to be inserted into the phalanges to which they are appropriated. In these Ungulata, too, as we need scarcely say, the *lumbricales* and *interossei* are quite deficient; and the short muscles of the thumb are completely developed only in Man and in the Quadrumana.

(2246.) It is in the human species only that the lower extremities are organized so as to maintain the body in the erect position; and in consequence, the *glutæi* muscles in the human body are enormously developed when compared with those of the lower animals; but the other muscles derived from the pelvis and thigh present but slight differences throughout the whole class under consideration. In the leg and foot likewise it is not difficult to identify the muscles that correspond to those found in the human subject, but, as in the anterior extremity, modified in their disposition and mode of insertion in accordance with the construction of the skeleton.

(2247.) The articulations whereby the different pieces composing the Mammiferous skeleton are connected to each other are constructed upon the same principles as in the human body, insomuch that to describe them even in general terms would be useless.

(2248.) The bones of the cranium and face, as in Man, are joined together by harmony or by suture. The articulations of the lower jaw are double, each presenting an interarticular cartilage, except in the Cetacea, where, instead of such a structure, a very thick, matted, ligamentous substance, having its interstices filled with oil, passes directly from the condyles of the jaw to the temporal bones.

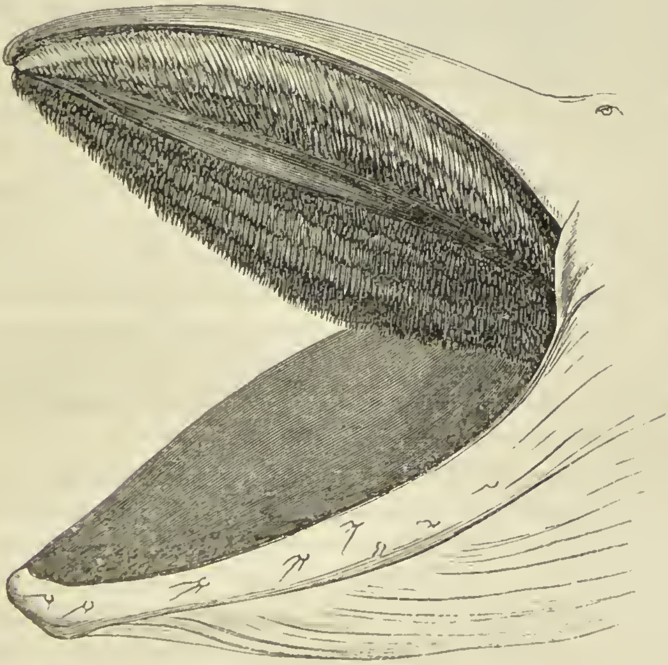
(2249.) The joints of the spine, thorax, and pelvis are all constructed upon the same principles as the corresponding articulations in the human subject; and the same may, with slight exceptions, be said of those of the extremities. The chief differences will be found in the connexion between the *radius* and *ulna,* the movements of rotation becoming gradually less manifest as we descend from Man: the *tibia* and *fibula,* too, ultimately become completely anchylosed to each other. The hip-joint contains an internal *ligamentum teres;* but in a few instances, *e.g.* the

Ornithorhynchus, the Echidna, the Sloths, the Elephant, the Seals, and the Orang-Outang, this round ligament is deficient. The arrangement of the other articulations will be at once apparent on reference to the figures of the different skeletons already given.

(2250.) Turning to the digestive system of Mammiferous animals, their teeth first invite our attention. We have already, when describing the osseous framework of these elevated beings, exposed their general arrangement in the jaws of the different orders; but it still remains for us to explain the varieties of their structure and the mode of their formation.

(2251.) The most remarkable form of teeth, one indeed that is unique, is met with in the Whalebone Whale (*Balæna mysticetus*). The teeth in this Cetacean, indeed, are not instruments of mastication, but form a very curious apparatus, adapted to strain the waves of the sea as through a sieve, and thus obtain from the ocean a sufficiency of food for the sustenance of its monstrous body.

Fig. 396.



Mouth of the Whalebone Whale.

(2252.) The whalebone (as it is improperly called) is attached to the gums of the upper jaw, being arranged in thin flat plates of some breadth, and varying in length according to the size of the Whale *. These plates are placed in several rows, similar to teeth in other animals; they stand parallel to each other, having one edge directed towards the circumference of the mouth. The outer row is composed of the longest plates, and these are in proportion to the varying distances between the two jaws, some being fourteen or fifteen feet long, and twelve or fifteen inches broad; but towards the anterior and posterior part of the mouth they are very short.

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* J. Hunter, on the Structure and Œconomy of Whales (Phil. Trans. 1787).

(2253.) Inferiorly each plate of whalebone is terminated by a broad fringe of horny fibres resembling hair; and, seeing that in some whales there are about three hundred plates composing the outer row on each side of the mouth, the reader may form some idea of the extent of this enormous strainer, whereby the little *Clio borealis,* and other small Mollusca that swarm so abundantly in the Northern ocean, are caught by shoals preparatory to their being swallowed.

(2254.) For what is known concerning the growth of whalebone, we are indebted to John Hunter; and as it would be difficult to curtail his clear and concise description of the process, it is here given in his own words *:—

(2255.) "The formation of whalebone is extremely curious, being in one respect similar to that of hair, horns, spurs, &c.; but it has besides another mode of growth and decay, equally singular.

(2256.) "These plates form upon a thin vascular substance, not immediately adhering to the jaw-bone, but having a more dense substance between, which is also vascular. This substance, which may be called the nidus of the whalebone, sends out thin, broad processes answering to each plate, on which the plate is formed, as the cock's spur or the bull's horn on the bony core, or a tooth on its pulp; so that each plate is necessarily hollow at its growing end, the first part of the growth taking place on the inside of this hollow.

(2257.) "Besides this mode of growth, which is common to all such substances, it receives additional layers on the outside, formed from the above-mentioned vascular substance, extended along the surface of the jaw. This part also forms upon it a semi-horny substance between each plate, which is very white, rises with the whalebone, and becomes even with the outer edge of the jaw. This intermediate substance fills up the spaces between the plates as high as the jaw; acts as abutments to the whalebone; or is similar to the alveolar processes of the teeth, keeping them firm in their places.

(2258.) "As both the whalebone and intermediate substance are constantly growing, and as we must suppose a determined length necessary, a regular mode of decay must be established, not depending entirely on chance, or the use it is put to. In its growth, three parts appear to be formed: one from the rising cone, which is the centre; a second on the outside; and a third, being the intermediate substance. These appear to have three stages of duration; for that which forms on the cone, I believe, makes the hair, and that on the outside makes principally the plate of whalebone: this, when got a certain length, breaks off, leaving the hair projecting, becoming at the termination very brittle: and the third, or intermediate * substance, by the time it rises as high as the edge of the skin of the jaw, decays and softens away like the old cuticle of the sole of the foot when steeped in water."

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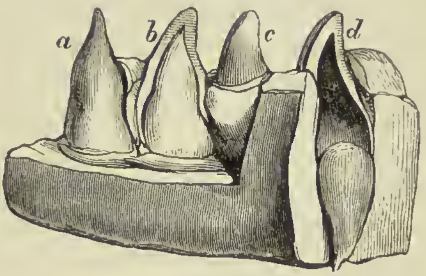
* *Vide supra.*

(2259.) Other kinds of teeth, met with among Mammals, are composed of calcareous earths deposited in a nidus of animal matter, and consequently resemble bones in the hardness of their texture. In their simplest form these teeth consist of but one kind of material, called ivory; and in such cases there is no distinction into classes as in the human subject, every tooth being conical, and formed upon a simple pulp. Such are the teeth of the Porpoises (*Delphinidæ*) and of the Cachalot Whales (*Physeter*). The example selected to illustrate their structure and mode of growth is a preparation of a portion of the jaw of the Bottle-nose Whale (*Delphinus tursio*), contained in the Hunterian collection †. From this it is seen (fig. 397) that each tooth of the Cetaceans in question is a hollow cone of ivory (*a*, *b*, *c*, *d*), which, on being split longitudinally, is found to contain a vascular pulp exactly filling up its internal cavity. It is upon the surface of this pulp that the ivory matter is produced and deposited, *stratum inter stratum*, within the tooth, thus gradually adding to its substance as growth proceeds. In animals possessing a dental apparatus of this description, Mr. Hunter observed that the teeth are not at first developed in the jaw, but appear to form in the gum upon the edge of the maxillary bones; and that they either sink into the jaw as they lengthen, or, as is more probably the case, the alveoli rise to enclose their roots as growth advances. It would moreover appear that these creatures do not shed their teeth, but that, as the jaw enlarges, new teeth are constantly produced from behind, while those towards the symphysis fall off, and their sockets become absorbed: thus the size of the teeth is made to keep pace with the increasing dimensions of the jaw ‡. The exact number of teeth met with in any species of these Whales will evidently be uncertain.

Fig. 397.



Teeth of the Porpoise.

(2260.) In the male Narwal (*Monodon*) there are no teeth implanted along the margins of the jaws; but from the intermaxillary bone of the left side of the face there projects a single tusk of great strength, which sometimes attains the length of eight or ten feet. This formidable weapon is fully developed only upon one side of the body; nevertheless the corresponding tooth exists in a rudimentary condition, enclosed in the opposite intermaxillary bone.

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* Mr. Hunter means by "intermediate," interposed between the contiguous plates, not between the "hair" and the laminated whalebone.

† Preps. Nos. 327 & 328.

‡ 'The Animal Œconomy,' by John Hunter, with Notes by Richard Owen, Esq., F.R.S., p. 353. London, 1837.

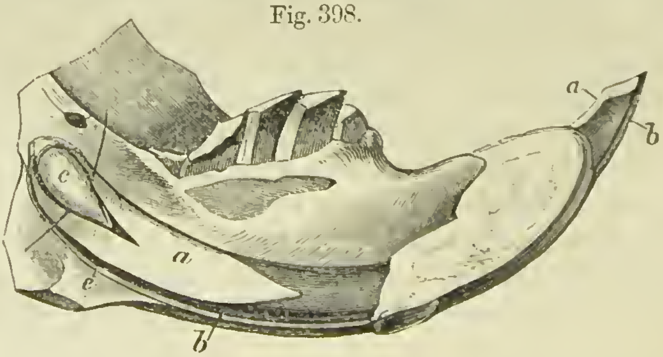
(2261.) In the Elephant (a creature which so obviously forms a connecting link between the gigantic Cetacea and terrestrial quadrupeds) tusks, more ponderous even than that of the Narwal, project from both intermaxillary bones: but these, as well as the tusks of other Pachydermata, grow upon a simple pulp, such as that which forms the teeth of the Bottle-nose Whale; are composed of ivory, without any enamel; and their growth is only limited by the abrasion to which they are subject.

(2262.) In by far the greater number of quadrupeds the teeth present a more complex structure, and consist of two distinct substances of very different texture—the one analogous to the ivory of the simple teeth described in the last paragraph, the other, called *enamel,* of crystalline texture and such extreme density as to withstand being worn away by acting upon the hardest materials used as food. Teeth of this description may be advantageously divided into two principal groups: first, those whose growth is continuous during the entire lifetime of the animal; and second, those which are completed at an early period, and then cease to grow.

(2263.) The first division includes the incisor teeth of the Rodentia, or *dentes scalprarii,* as they have been termed. Such teeth are, in fact, chisels of most admirable construction, destined to gnaw the hardest kinds of food, and yet never to all appearance wearing away or becoming blunted by use.

(2264.) The annexed figure (398) represents a section of the incisor tooth and of the left ramus of the lower jaw of a Porcupine (*Hystrix cristata*); and from this example the structure of such teeth will be readily understood. The bulk of the tooth consists of solid ivory (*a*).

Fig. 398.



Growth of incisor tooth in the Porcupine.

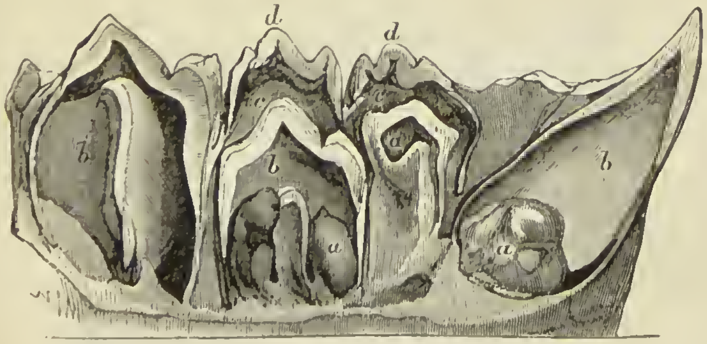
which in its texture and mode of growth resembles that of a simple tusk, being continually growing from behind by the addition of new matter produced from the vascular pulp (*c*); so that, were such a tooth not worn away constantly at the point, it would curl up over the face like the tusk of the Babiroussa: and if by accident the opposing tooth in the upper jaw should be broken off, this circumstance in fact really takes place.

(2265.) But, besides the ivory-forming pulp (*c*), there is a vascular membrane which exists only upon the anterior surface of the socket, its limits on each side being distinctly marked by a defined line. This membrane secretes enamel, and coats the convex surface of the tooth with a thin layer (*b*) of that dense substance. From this beautiful arrangement it results that, while the anterior end of the tooth is perpetually worn away by attrition against hard substances, the ivory is abraded more rapidly than the enamel that coats it in front; thus, therefore, the tooth constantly preserves its chisel-like shape, and presents the sharp cutting-edge formed by the layer of enamel.

(2266.) The second kind of teeth, composed of bone and enamel, are limited in their growth; and the entire crown or projecting portion is invested with enamel covering its surface. The teeth of all the CARNIVORA, of the QUADRUMANA, and also of MAN, are of this description. From marked differences in their form in different regions of the mouth, such teeth are conveniently divisible into different groups, called respectively *incisores*, *laniares* or canine teeth, *pseudo-molares* or false grinders, and *molares* or grinding teeth.

(2267.) Whatever may be the shape of teeth of this class, their mode of growth is similar to that observed in those of our own species. We have chosen, in order to illustrate this, the growing permanent teeth of a young Lion, wherein the different organs employed in their formation are easily distinguishable. The ivory that forms the bulk of the tooth (fig. 399, *b*) is formed by the surface of an internal pulp (*a*); and as it slowly accumulates, encroaching upon the central cavity, and penetra-

Fig. 399.



Growing teeth of a young Lion.

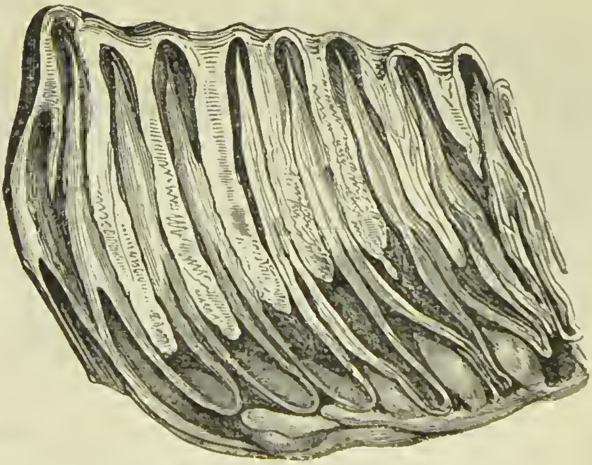
ting more deeply into the socket, the fang is gradually formed, and the central pulp shrinks until, in the fully-formed tooth, it becomes reduced to a thin membrane richly supplied with vessels and nerves, which lines the small central cavity that remains.

(2268.) Before the progressively advancing tooth issues from the nidus wherein it is produced, the enamel is deposited upon the surface of the ivory by the lining membrane of the capsule (*c*), and becomes arranged in crystalline fibres placed perpendicularly to the surface of the ivory, until the whole crown of the tooth is adequately coated with this important additional substance. Meanwhile the growth of the tooth still proceeds by the lengthening of its root, until at last the crown issues from the jaw, and the enamel-secreting membrane (*c*) becomes obliterated.

(2269.) The most complex condition of the dental organs is that found in the molar teeth of herbivorous quadrupeds, which, being destined to act the part of millstones in grinding down and comminuting vegetable substances, must necessarily, like the millstones of human contrivance, have a grinding surface, presenting prominent edges and deep sulci, not liable to become worn even by the continual abrasion to which they are subjected. In order to attain this end, the ivory and enamel interdigitate, as it were, in the substance of the tooth, and are, moreover, imbedded in a third material, not met with in the simpler forms, called the *cementum* or *crusta petrosa*. In consequence of this arrangement, seeing that the plates of ivory, of enamel, and of cement are all of different degrees of hardness, the softer substances are most easily worn away, and thus these compound teeth always offer an efficient grinding surface.

(2270.) By inspecting the accompanying figure (fig. 400) represent-

Fig. 400.



Structure of the molar teeth of the Elephant.

ing a section of the tooth of an Elephant, the disposition referred to will be better understood: the layers of enamel are seen to alternate with plates of ivory, while all the interstices are filled up by the circumfused *cementum*.

(2271.) During the growth of a compound tooth of this description, the enamel-secreting membranes derived from the capsule of the tooth, of course, interdigitate with the ivory-forming pulps that arise from the bottom of the sockets, and thus the hard materials formed by them take the same arrangement. After these structures have been completed, one or other of the sets of pulps, most probably the enamel pulps, changing their action, fill up all the intervening spaces with the *crusta petrosa*.

(2272.) As during the growth of a quadruped the size of the jaws is continually increasing, a necessity exists for changing the teeth once or oftener during the life of the animal, in order to adapt these organs to the altered conditions required: hence the necessity for shedding the teeth of young animals, and replacing them with others of larger dimensions or more numerous than the first set.

(2273.) This is effected in two different ways, each of which demands our separate notice.

(2274.) In most quadrupeds, as, for example, in the Carnivora, the Quadrumana, and the greater number of herbivorous genera, the succession of the teeth is provided for precisely in the same way as in our own species, namely, by the formation of a new tooth below each of the deciduous ones (fig. 399, *d d*); so that when the latter falls out in consequence of the absorption of its fangs, the former is ready to take its place. The germ of the second tooth is at first found imbedded in the jaw-bone, in the immediate vicinity of the roots of the one which it is destined to replace; and as its growth advances, the old and used tooth is gradually removed to make way for the new comer. The steps of this process are exactly similar to those by which the milk-teeth of a child are changed, and the details connected with it are familiar to every anatomist.

(2275.) But in the Elephant, and some other genera of PACHYDERMATA, the succession of the teeth is effected in a different manner, the place of the first-formed being supplied by others that advance from behind as the former become used. Animals exhibiting this mode of dentition have the grinding surfaces of their molar teeth placed obliquely *; so that if they were to issue altogether from the gum, the anterior portion would be much more prominent than the posterior, notwithstanding that the opposed teeth act upon each other in a horizontal plane. The consequence of this arrangement is, that the anterior portion of these teeth is ground down to the roots, and worn away sooner than the posterior portion. Moreover the posterior part of the tooth is considerably wider than the anterior; so that, as the succeeding tooth advances from behind, there is always sufficient room to receive it; and in this way, by the time that the first tooth is quite destroyed and falls out, a new one from behind has already taken its office. There is, therefore, no absorption of the roots of these teeth, but they are ground down from the crown to the stump.

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* Cuvier, Leçons d'Anat. Comp. iii. p. 122.

(2276.) The new tooth that thus advances from behind is always of larger dimensions than that to which it succeeds, because the animal itself has grown in the interval, and the jaws have become proportionally developed.

(2277.) The Elephant in this way may have a succession of seven or eight teeth on each side in both jaws, or from twenty-eight to thirty-two in all; and nevertheless, seeing that the anterior ones successively fall out, there are never more than two visible at once above the gums on each side, or eight in all; generally, indeed, there is only one visible at a time. Every successive tooth is composed of more laminæ than that which immediately preceded it, and a longer time is required to perfect its growth.

(2278.) Nearly the same account of this process was found in the Manuscripts of John Hunter *, who lucidly accounts for such an aberration from the ordinary course of proceeding. "These creatures," says that distinguished observer of Nature, "do not shed their teeth as other animals do that have more than one; for those that have more than one tooth can afford to be for some time without some of their teeth: therefore the young tooth comes up in many nearly in the same place with its predecessor, and some exactly underneath; so that the shedding tooth falls sometimes before the succeeding tooth can supply its uses. But this would not have answered in the Elephant; for if the succeeding tooth had formed in the same situation with respect to the first, the animal would have been for some time entirely deprived of a tooth on one side,—or, at least, if it had one on the same side in the opposite jaw, that one could have been of no use; and if this process took place in both sides of the same jaw, and in either jaw, the animal would have been entirely deprived of any use of the two remaining."

(2279.) The teeth of Mammalia being thus adapted to so many various offices, and serving, under different circumstances, to hold, to bruise, to cut, to tear, or to grind alimentary substances, we must naturally expect the movements of which the lower jaw is capable to be in correspondence with the nature of the dental apparatus.

(2280.) In Man, as the student well knows, in consequence of the laxity of the ligaments that connect the inferior maxilla with the temporal bone, and the thickness of the articular cartilage that is interposed between the convex surface of the condyle and the shallow glenoid cavity, every kind of motion is permitted, in conformity with the omnivorous habits of the human race; and the temporo-maxillary articulation is no longer a mere hinge, but the teeth can be made to act upon

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* Descriptive and Illustrated Catalogue of the Physiological Series of Comparative Anatomy in the Museum of the Royal College of Surgeons of London, Part i. p. 100.

each other by rubbing their grinding surfaces in all needful directions. In the Herbivorous quadrupeds these triturating motions are likewise extensive. In the RODENTIA the movements of the lower jaw are principally backwards and forwards, thus giving free play to their chisel-like teeth whilst employed in eroding hard substances; and in the CARNIVORA, where there is no necessity for any grinding motion, the condyle is so locked into a deep and transverse glenoid cavity, that the movements of a hinge only are permitted.

(2281.) But whatever the degree of motion conferred upon the lower jaw, the muscles that act upon it are exactly comparable to those of the human subject. The *masseter* is strengthened in proportion to the hardness of the substances used for food; the *temporal* covers a greater or less extent of the cranium as the jaws are stronger or more feeblo; and even tho *pterygoid* muscles differ only in relative size and form from those of Man.

(2282.) The *digastric* muscle, however, which is an important agent in depressing the lower maxilla, does not preserve the same arrangement in the lower quadrupeds that it presents in the human species. In Monkeys, indeed, it still exhibits two fleshy bellies, and a central tendon that traverses the *stylo-hyoideus*; but in general it is a single fleshy muscle, arising from the neighbourhood of the mastoid process, and inserted near the angle of the jaw.

(2283.) The *tongue*, in nearly all the Mammifera, is composed of the same muscles as in Man; and their disposition is so similar as to render any detailed enumeration of them quite unnecessary. The only exceptions worthy of notice are found in the Ant-eater (*Myrmecophaga*) and in the *Echidna*, animals possessing tongues of remarkable length and slenderness, by means of which they secure their insect prey.

(2284.) In both these animals the tongue suddenly becomes much contracted at the place where it begins to be free from the surrounding parts. It then appears to be made up of two very long and slender muscular cones, laid one upon the back of the other, their apices being at the end of the tongue*. Each of these cones consists of two muscles: one external, composed of a multitude of distinct fasciculi investing tho internal muscle in a circular manner, and forming around it numerous little rings resembling the annelli of an earthworm. The internal muscle, on the contrary, is of great length; it arises from the middle and upper part of the sternum, runs forward along tho neck, passes between two layers of the *mylo-glossus*, and afterwards becomes surrounded by the annular muscle; it is composed of distinct fasciculi, rolled upon themselves in an elongated spiral; the external fibres terminate at the first rings; those beneath attain tho rings that succeed, and so on until the innermost fibres reach quite to the extremity of the tongue. It is easy to perceive that, by its action, this musclo will shorten the tongue until it lies in a very small compass, or bend it in any direction; whilst the annular muscle will lengthen it, exactly in the same way as the body of a leech is extended or contracted.

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* Cuvier, Leçons d'Anat. Comp. iii. p. 264.

(2285.) In the Ant-eater the annular muscle does not appear so distinctly double as it does in the Echidna; but it forms by itself almost all the substance of the tongue, which is thus capable of being elongated to a wonderful extent.

(2286.) Regarding the tongue with reference to the sense of taste, the Mammalia may be looked upon as the only animals capable of receiving much enjoyment from this source, since in them alone the lingual mucous lining seems to be perfectly adapted to gustation. Even among these highly-endowed creatures, it is only in Man, and those Herbivorous orders that prepare their food in the mouth by a prolonged mastication, that the sense in question exhibits much delicacy of perception; for the Carnivorous quadrupeds, seeing that they tear to pieces and swallow their food in large morsels, can scarcely be supposed to pay much attention to its sapid qualities.

(2287.) In the Cat tribe (*Felidæ*), indeed, all the middle portion of the surface of the tongue is covered over with sharp, recurved, and horny spines, adapted, as it were, to file off remnants of soft flesh from the bones of their victims; and the gustatory papillæ are elsewhere of small dimensions. The tongue of the Porcupine, likewise, is armed on each side near its extremity with broad, horny and sharp scales; but, with these exceptions, the mucous covering of the tongue, the various kinds of papillæ upon different parts of its surface, and, moreover, the distribution of the nerves supplied to it, differ in no important circumstance from what is observed in the human organ of taste.

(2288.) Importantly connected with the perfection of the sense of taste, and materially assisting in the mastication of food, is the salivary apparatus, which, throughout all the Mammalia, is made up of glands that offer the same general arrangement as in Man.

(2289.) The *parotids* vary principally in their proportionate size; and their ducts always perforate the lining membrane of the mouth in the vicinity of the molar teeth.

(2290.) The *submaxillary* and the *sublingual* glands are also very generally present; and, as in the human subject, the saliva that they furnish enters the mouth beneath the under surface of the tongue.

(2291.) The mucous lining of the lips and cheeks is likewise studded with muciparous follicles, called, from their situation, *buccal*, *molar*, or *labial* glands; these likewise serve to lubricate the oral cavity.

(2292.) In the Seals (*Phocidæ*) there are no parotids, neither are these glands found in the *Echidna hystrix*, or in the Ant-eater (*Myrmecophaga*); but in the last-named genus their place is supplied by two other secreting organs, of which Cuvier gives the following description*.

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* Leçons d'Anat. Comp. iii. p. 215.

One is in contact inferiorly with the upper edge of the *masseter* muscle, and fills up a great part of the space that represents the temporal, zygomatic, and orbital fossæ, where it partially embraces the globe of the eye: the excretory duct derived from this gland opens into the mouth, behind the superior maxillary bone. The other, which is probably destined to furnish the viscid secretion that coats the worm-like tongue of this animal, is oval and flat, lying in front of the tendon of the masseter, behind the angle of the lips, and then running along the edge of the lower lip as far as its middle. Its canal opens externally in a groove at the commissure of the lips; and a white, thick and tenacious fluid may be pressed out from the cells of which the gland seems to be made up.

(2293.) In a few species, in addition to the salivary glands met with in Man *, there is a group, apparently a continuation of the molar, which mounts up along the superior maxillary bone, beneath the *zygoma*, even to behind the globe of the eye. The excretory ducts derived from this group pierce the mucous membrane near the posterior margin of the superior alveolar ridge. Such an arrangement is met with in the Ox, the Sheep, and the Horse.

(2294.) In the Amphibious Mammalia the salivary system is very feebly developed; and in the Cetacea, as might be expected from their habits, no salivary glands whatever are to be detected.

(2295.) Before considering the mechanism of deglutition in the Mammalia, we must, in the next place, briefly describe their *hyoid apparatus*; more especially as this remarkable system of bones, which in the lower Vertebrata was so importantly connected with the respiratory function, is now reduced to an extremely simple condition, and, although it is still intimately connected with the *larynx*, is more particularly remarkable as forming a centre of attachment for almost all the muscles of the throat.

(2296.) Perhaps there is no part of the bony framework of the body that exemplifies more strongly than the *os hyoides* the impossibility of attaining correct physiological views relative to the composition of the skeleton by the mere examination of the human subject. Let the student, for instance, compare for a moment the *os hyoides* of Man with that of the Fish, or of the Amphibious Reptile, and endeavour, in the simple segment of a circle presented by the one, to find the analogues of the body and complicated arches of the others; then, doubtless, he will find that, without some intermediate gradations of form, it is not easy to trace the slightest relationship between them.

(2297.) The human *os hyoides* consists of a central portion and two cornua; but these are generally so completely consolidated as to form but one bone, which is connected by the interposition of a broad ligament with the upper margin of the thyroid cartilage; moreover two smaller appendages, called the *lesser cornua,* are articulated with the upper surface of the hyoid bone, close to the point of junction between the *cornua majora* and the *body,* from whence ligaments, called the *stylo-hyoid,* pass upwards and backwards to the styloid processes of the temporal bone.

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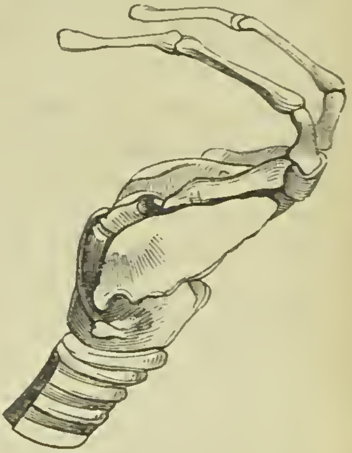
* Leçons d'Anat. Comp. iii. p. 210.

(2298.) All the apparatus of hyoid arches passing between the body of the bone and the base of the cranium, which were so largely developed in the lower Vertebrata, have therefore totally disappeared; and the question to be solved is, how we may identify the remaining portions with any of the elements of the more complex structures that have come under our notice.

(2299.) Difficult as this would be to the student who had confined his attention to the human body, on referring to the *os hyoides* of a quadruped, one of the Carnivora for instance, the analogies become at once perceptible. The body (fig. 401) is evidently the representative of the central portion of the hyoid apparatus in Fishes, in Reptiles, and in Birds, which have been described in preceding pages. The lingual elements, found even in Birds, are quite obliterated; but two arches still remain. The posterior of these (fig. 401), which represent the larger cornua of the human *os hyoides,* do not reach the cranium, but, as in Man, are attached by muscle and ligament to the thyroid cartilage; while the anterior cornua, so small in Man, are in quadrupeds by far the largest, each consisting of two pieces, of which the second are articulated with the extremities of the styloid bones, and these last are in turn joined to the temporal bones by means of articulating surfaces. In Man the styloid bones become anchylosed with the temporal, giving rise to the "styloid processes;" and the intermediate pieces of the anterior cornua have their places supplied by ligaments (the *stylo-hyoid*): in this way, therefore, the hyoid apparatus attains the form that it exhibits in the human skeleton.

Fig. 401.



Os hyoides.

(2300.) The muscles connected with the *os hyoides* in quadrupeds correspond with those met with in the human body; and their action in effecting the deglutition of food is well known to the anatomical reader.

(2301.) The passage of the fauces in the Mammalia presents an organization peculiar to the class, and exhibits structures adapted to prevent alimentary materials from entering the air-passages during the operation of swallowing. The most remarkable of these is the epiglottis, forming a valvular fibro-cartilaginous lid, that accurately closes the opening of the larynx during the transit of food into the throat. The communication between the posterior nares and the faucial cavity is likewise protected by a musculo-membranous valve, called the *velum pendulum palati*; but as, with the exception of the Cetacea, hereafter to be noticed, the arrangement of these parts exactly resembles what is seen in the human subject, it would be superfluous to describe them more minutely in this place.

(2302.) The bag of the pharynx in all the Mammalia is similar in its structure to that of Man; and its muscles, namely, the *stylo-pharyngeus* and the three *constrictors*, although stronger than in our own species, offer no differences worthy of more particular notice.

(2303.) The œsophagus, leading from the termination of the pharynx into the stomach, is a long muscular tube that traverses the chest in front of the bodies of the dorsal vertebræ, and, having pierced the diaphragm, reaches the abdominal cavity. Its lining membrane is loose and much plicated, so as to allow of considerable dilatation; but externally its walls are very muscular, tho surrounding muscles being arranged in two distinct layers. In Man the outer stratum of muscular fibres is disposed longitudinally, while the inner layer consists of circular fibres; but in most other Mammalia both these layers assume a spiral course, and cross each other obliquely as they embrace the œsophageal tube.

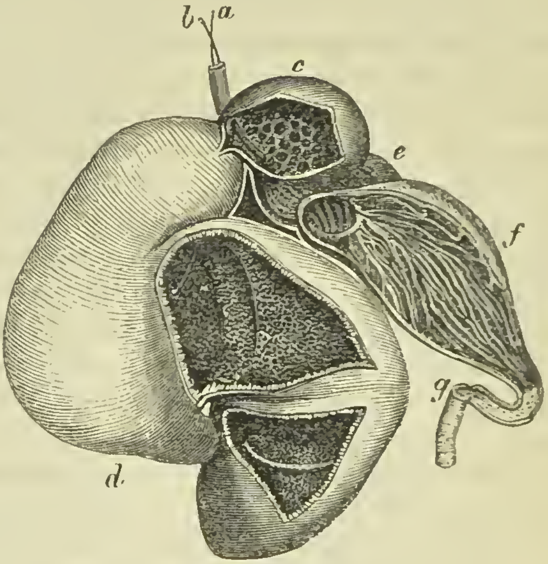
(2304.) The stomach itself presents such endless diversity of form, that merely to enumerate all the details that have been amassed relative to this part of our subject would fill many volumes, without perhaps at all advancing our real knowledge concerning the progress of digestion; we must therefore content ourselves with a very general view of the organization of this important viscus, and regard the Mammalia as possessing either *simple*, *complex*, or *compound* stomachs, each of which will deserve a distinct notice.

(2305.) In the *simple* form of stomach the organ consists of a single cavity, as is the case in the human species: let the shape of tho viscus be elongated, pyriform, or globular (for in this respect there is every possible variety); whatever its form, or the relative positions of the cardiac and pyloric orifices, its structure corresponds with that of Man in all essential particulars. This kind of stomach exists in by far the greater number of Mammals.

(2306.) In the *complex* stomach tho viscus is mado up of several compartments communicating with each other, but without presenting any difference of organization such as in the present stato of physiological knowledge would lead us to suppose them to possess different functions: neither are we at all able to find any connoxion between such an arrangement and the nature of the substances used as food. The Kangaroo (*Macropus major*), the Kangaroo Rat (*Hypsiprymnus*), the Porcupine (*Hystrix*), and the *Hyrax* are amongst the most striking examples.

(2307.) The *compound* stomach is that possessed by the RUMINANTIA, or animals that chew the cud, and consists of four distinct cavities, differing very materially both in their size and in the arrangement of their lining membranes. The first and by far the largest cavity (fig. 402, *d*) is called the paunch (*rumen*), and is of very great size, occupying a considerable portion of the abdominal cavity, and forming the great receptacle into which the crude vegetable aliment is received when first swallowed: this chamber is lined with shaggy villi. The second cavity (*reticulum*) (*c*) is much smaller, and its walls are covered with numerous polygonal cells, from whence it derives the name it bears. The third chamber (*e*), called the *psalterium*, has its lining membrane disposed so as to form deep lamellæ, arranged longitudinally in alternating large and small layers, and thus presenting a most extensive surface. The fourth stomach (*abomasus*) (*f*) also exhibits very numerous folds of mucous membrane: it is of a pyriform shape, and by its smaller end terminates at the pylorus (*g*). The three first stomachs are lined internally with a thin cuticular investment; but the last, apparently the representative of the single stomach of those quadrupeds that have but one stomachal cavity, is coated with a soft membrane that furnishes abundantly the ordinary gastric secretions, and appears to be more especially the digestive stomach.

Fig. 402.



Stomach of the Sheep.

(2308.) The passage of the food through these different chambers will be easily understood on referring to the preceding figure, in which the course of the aliment before and after rumination is indicated by the direction of the probes *a*, *b*. The œsophagus, it will be observed, communicates on the one hand with the paunch (*d*), and on the other with the cavities *c*, *e*, *f*; and, moreover, by means of a muscular fold formed by the walls of the second cavity, a passage may be formed leading directly into the third stomach (*e*) without communicating with the second (*c*). The process of rumination, therefore, would seem to be effected in the following manner:—The herbage when first swallowed in an unmasticated condition passes into the capacious paunch (*d*), where it accumulates, and undergoes, no doubt, a kind of preliminary maceration. When the Ruminant has done grazing, and is at leisure, the food is again regurgitated into the mouth, to undergo more careful and complete mastication: for this purpose, a part of it is admitted into the *reticulum* (*c*), and there formed into a smooth and lubricated bolus, which, being expelled into the œsophagus, is immediately seized by the spiral muscles surrounding that canal and forced forwards into the mouth. After undergoing a thorough trituration, the aliment is once more swallowed, and it then enters into the third stomach (*e*), passing along the muscular fold that leads from the œsophagus into that compartment. Here it is spread out over the extensive surface formed by the laminated walls of the *psalterium*, and is prepared for admission into the last cavity (*f*), which, as has been said, is the true digestive stomach.

(2309.) While the young Ruminant continues to be nourished by its mother's milk, the three first cavities are undeveloped and comparatively very small; so that the milk passes on immediately into the fourth stomach, to be at once appropriated as aliment.

(2310.) In the Camel, the Dromedary, and the Llama, the walls of the reticulum and of a portion of the paunch are excavated into deep cells or reservoirs bounded by muscular fasciculi, wherein water may be retained in considerable abundance, unmixed with the contents of the stomach: it is in consequence of this arrangement that these animals are able to subsist for many days without needing a fresh supply of water even during long journeys in a tropical climate.

(2311.) In the CETACEA the stomach consists of several bags that communicate with each other. These bags vary from five to seven in number; but in the present state of our knowledge concerning the physiology of digestion it is difficult to divine what is the purpose of such an arrangement, more especially as rumination is here out of the question. The first stomach of the Whale, however, is no longer merely a reservoir*, as the food undergoes a considerable change in it. The flesh of its prey is entirely separated from the bones, which proves that the secretion of this cavity has a solvent power. This was found to be the case in the Bottle-nose Porpoise and in the large Bottle-nose Whale, in both of which several handfuls of bones were contained in the first cavity, without the smallest remains of the fish to which they had belonged. In others the earth had been dissolved, so that only the soft parts remained; and, indeed, it is only partially-digested materials that can be conveyed into the second and third cavities, the orifices being too small to permit bones to pass.

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* Sir E. Home, Lectures on Comparative Anatomy, vol. i. p. 225.

(2312.) The rest of the alimentary canal in most quadrupeds, like that of Man, is divisible into the small and the large intestines,—the division between the two being marked by one or even two appendages, called respectively the *cæcum* and the *appendix vermiformis.*

(2313.) The small intestines require no particular description, as in all minor circumstances, such as their proportionate length and diameter, or in the number and arrangement of the *valvulæ conniventes,* they do not differ from the human. The large intestines, however, offer very great variations of structure, and will therefore merit our more attentive consideration; we shall accordingly lay before the reader the following *résumé* of the principal facts connected with this subject, as given by the indefatigable Cuvier *.

(2314.) In Man, the Orang (*Simia*), and the Wombat (*Phascolomys*), both cæcum and vermiform appendage are met with.

(2315.) In the other Quadrumana, the Digitigrade Carnivora, the Marsupialia, the Rodentia, the Pachydermata, the Ruminantia, the Solipeds, and the Amphibious Mammals, there is a cæcum without any vermiform appendage.

(2316.) Neither *cæcum* nor *appendix vermiformis* is found in the Edentata, the Plantigrade Carnivora, nor in the Cetacea.

(2317.) Numerous exceptions, of course, occur to the above summary; but it would be useless to notice them in a survey so general as the present.

(2318.) Even where no cæcum exists, the separation between the large and small intestines is generally indicated by a valve (*ilio-colic*) formed by the lining membrane of the bowel: this, for example, is the case in the Sloths and Armadillos.

(2319.) In all the Mammalia that possess a cæcum, this organ appears to be a prolongation of the *colon* beyond the point at which the small intestine enters its cavity. The cæcum thus formed varies materially, both as relates to its size, shape, and structure: in animals that live upon vegetables, and even in some that are omnivorous, it is generally very large, gathered into sacculi, and often distinctly glandular; but in such as live upon flesh it is always small, and its cavity smooth, resembling a small intestine.

(2320.) The assistant chylopoietic viscera, namely, the *liver*, the *pancreas*, and the *spleen*, are constructed upon the same principles as in the human subject, and, except in a few minor circumstances, offer little to arrest our particular notice.

(2321.) The liver occupies the same position as in Man, being principally situated in the right hypochondrium, where it is securely suspended by broad folds of peritoneum connecting it to the abdominal surface of the diaphragm and to the circumjacent parts. It is most frequently, especially in the more active carnivorous families, divided by deep fissures into several lobes, a disposition whereby the free movement of this part of the body is evidently facilitated. The *gall-bladder,* when present, which is not invariably the case, receives the bile indirectly through a cystic duct derived from the hepatic ; so that the biliary fluid, poured into the duodenum through a *ductus communis choledochus,* is derived either immediately from the liver, or is regurgitated from the gall-bladder as occasion requires.

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* Leçons d'Anat. Comp. iii. p. 465.

(2322.) The *pancreas* resembles the human in every particular ; and its secretion enters the duodenum at the same point as that of the liver.

(2323.) The *spleen* is always attached to the stomach by a duplicature of the peritoneal lining of the abdomen, and is organized in the same manner as that of Man, except in the CETACEA, where this viscus is divided into several small portions quite distinct from each other.

(2324.) The system of the *vena portæ* is made up of the venous trunks derived from the spleen, the stomach, the pancreas, and the intestinal canal: these all unite to form one large central trunk, which, after entering the liver, again divides and subdivides minutely in that viscus, and furnishes the venous blood, from which the bile is principally, if not entirely, elaborated.

(2325.) The *peritoneum,* or the serous membrane lining the abdominal cavity, forms in the Mammalia a shut sac, and by its numerous inflexions invests all the chylopoietic viscera, forming broad mesenteric folds to support the intestines ; it thus encloses between its laminæ the entire system of mesenteric vessels, and also the lacteals derived from the alimentary canal: as to the rest, its structure and disposition, even to the formation of the omental sacs, differ in no important respect from what is found in the human body.

(2326.) The chyle, the result of the digestive process, is taken up from the mucous lining of the intestinal canal by innumerable microscopic orifices that form the commencement of the *lacteal system,* which in the Mammalia seems to assume its most perfect development. This important system of absorbent vessels consists of slender canals enclosed between the two layers of the mesentery, to the root of which they converge from all the tract of the intestine. The valves formed by the lining membrane of these tubes are in Mammals so numerous and perfect that it is no longer possible to inject them from trunk to branch. Before terminating in the *thoracic duct,* these vessels permeate numerous "*mesenteric glands,*" as they are called, by means whereof they appear to communicate freely with the venous system; but the bulk of the matter absorbed enters a kind of reservoir called the "*receptaculum chyli,*" whence, by means of the *thoracic duct,* the chyle is conveyed to be mixed up with the mass of circulating fluid, and is ultimately poured into the *vena innominata* at the junction of the jugular and subclavian veins of the left side of the body.

(2327.) The *lymphatic system* of Mammals, as far as it has been studied, conforms in its arrangement to that of Man.

(2328.) Neither will it be at all necessary to describe at any length the construction of the respiratory and circulatory organs in the class now under consideration, seeing that the structure of the lungs, the mechanism of respiration, the arrangement of the pulmonary vessels, the cavities of the heart, and the general disposition of the arteries and veins of the systemic circulation differ in no material circumstance from what is met with in the human subject.

(2329.) The lungs, occupying the two sides of the chest, are each contained in a distinct chamber, formed by the ribs and diaphragm, without in any part adhering to its walls. Each lung is enclosed in a serous cavity formed by the pleura, which, after lining the ribs, the intercostal muscles, and the thoracic surface of the diaphragm, is reflected on to the lung itself at the point occupied by the roots of the pulmonic vessels, and invests the entire surface of the viscus; it moreover passes deeply into those fissures that separate the lung into several distinct lobes.

(2330.) In the interspace between the two pleuræ, called the *mediastina*, is lodged the heart, contained in a fibro-serous envelope (the *pericardium*); and behind this, the œsophagus, accompanied by the principal trunks of the vascular system, passes through the thorax into the abdomen.

(2331.) Each lung is a closed bag, composed of innumerable cells that communicate with the terminations of the bronchial tubes, and collectively present an immense surface, over which the blood contained in the capillaries of the pulmonary vessels is made to circulate.

(2332.) The inspiration and expiration of air are effected by the alternate movements of the diaphragm and of the walls of the thoracic cavity, whereby the atmospheric fluid is drawn into and expelled from the pulmonary cellules, and is thus constantly renewed as it becomes deteriorated by the abstraction of the oxygen consumed during the process of converting the venous into arterial blood.

(2333.) The purified blood, after passing through the pulmonary capillaries, is collected in an arterialized condition by the pulmonary veins, and conveyed to the systemic side of the heart, which offers the same arrangement throughout the entire class, consisting of an auricular chamber (fig. 403, *c*) and of a very muscular ventricle (*a*), the auriculo-ventricular opening being guarded by *mitral valves* and *columnæ carneæ*, similar to those found in the human heart. From the left ventricle the blood is driven into the aorta (*e*), the commencement of which is guarded by three semilunar valves, and thus it passes through the entire system.

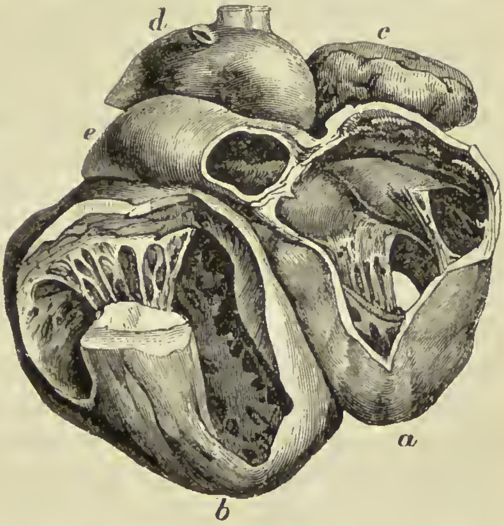
(2334.) When again collected from the periphery of the body, the now vitiated fluid is returned to the heart by the venous system, and poured through the *venæ cavæ* into the right or pulmonic auricle; and hence it passes into the right ventricle (fig. 403, *b*), to be again returned through the *pulmonary artery* to the lungs, thus completing the circulation.

(2335.) But although the general arrangement of the circulatory and respiratory organs in all Mammals thus in every respect resembles that which exists in the human body, there are of necessity variations in the distribution of certain parts of the sanguiferous system, adapted to the peculiarities of organization presented by the different orders and even families of this great class, which must not be wholly passed over in silence.

(2336.) In the Cetacea, for instance, many interesting circumstances are observable in the arrangement of the vascular system.

(2337.) In the herbivorous genera, as for example in the Dugong, the two sides of the heart are separated to a considerable extent by a deep fissure (fig. 403, *a*, *b*), so that the pulmonary and systemic hearts are much more evidently distinct viscera than they appear to be in the quadrupedal forms; nevertheless in the Whalebone and Spermaceti Whales the heart assumes the usual appearance, and is only remarkable for its amazing size; this, indeed, may well have attracted the notice of Hunter* while investigating such gigantic beings. "In our examination of particular parts," says that eminent anatomist, "the size of which is generally regulated by that of the whole animal, if we have only been accustomed to see them in those which are small or middle-sized, we behold them with astonishment in animals so far exceeding the common bulk as the Whale. Thus the heart and aorta of the Spermaceti Whale appeared prodigious, being too large to be contained in a wide tub, the aorta measuring a foot in diameter. When we consider these as applied to the circulation, and figure to ourselves that probably ten or fifteen gallons of blood are thrown out at one stroke, and moved with an immense velocity through a tube of a foot in diameter, the whole idea fills the mind with wonder."

Fig. 403.



Heart of the Dugong.

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* The Animal Œconomy, by J. Hunter, with Notes by Professor Owen, p. 366.

(2338.) In the arrangement of the blood-vessels of the Cetacea, many interesting peculiarities are met with *. The general structure of the arteries, indeed, resembles that of other Mammals, and, where parts are nearly similar, their distribution is likewise similar. But these animals have a greater proportion of blood than any others known; and there are many arteries apparently intended as reservoirs, wherein a large quantity of arterial blood may accumulate apparently for important purposes, where vascularity could not be the only object. Thus the intercostal arteries divide into a vast number of branches, which run in a serpentine course between the pleura and the ribs, and penetrate the intercostal muscles, everywhere lining the walls of the thorax. These plexiform vessels, moreover, pass in between the ribs near their articulation, and anastomose extensively with each other. The *medulla spinalis* is likewise surrounded with a network of arteries in the same manner, more especially as it comes out from the brain, where a thick substance is formed by their ramifications and convolutions; and these vessels most probably anastomose with those of the thorax. The precise function assigned to this extensive plexus of arteries has not been as yet satisfactorily determined, although it is doubtless a receptacle wherein arterial blood is stored up during the long-continued submersion to which these animals are so frequently subjected.

(2339.) As the Cetacea have no pelvic extremities, the aorta, instead of bifurcating into iliac arteries, is entirely appropriated to supply the enormous tail, beneath which it is continued, enclosed in a canal formed by the roots of the inferior spinous processes of the caudal vertebræ, that are here again developed as in fishes.

(2340.) The venous system in the Cetacean order is equally remarkable for the plexuses formed by it in different parts of the body: of these, the most important communicates with the abdominal cava, and is of immense extent. The veins of these creatures, moreover, are almost entirely deprived of valves; so that every possible arrangement has been made to delay the course of the circulating blood during the temporary suspension of respiration that occurs whenever the animal plunges beneath the surface of the water.

(2341.) In other aquatic Mammals that dive, and are thus subjected to prolonged immersion, large dilatations are found connected with the principal trunks of the venous system in the neighbourhood of the heart, in order to prevent a dangerous distension of these veins while the circulation is impeded and respiration put a stop to. This is particularly remarkable in the Seal tribe; and in these Carnivora we are assured by good authorities that it is not uncommon to find the *foramen ovale* of the heart, and the *ductus arteriosus*, which in the fœtus allows blood to pass from the pulmonary artery directly to the aorta, still open even in the adult animal; but this arrangement, as we are well satisfied,

* Hunter, *ut supra*, p. 365.

is by no means to be regarded as the normal structure of the heart in a Seal.

(2342.) In many of the long-necked herbivorous quadrupeds a peculiar provision has been made in the disposition of the internal carotid arteries, apparently intended to equalize the force of the blood supplied to the brain in different positions of the head: for this purpose the arteries referred to, just as they enter the skull, divide into several branches, which again unite so as to assume a kind of plexiform arrangement, forming what is called the *rete mirabile* of old authors. The effect of this subdivision of the main trunk into so many smaller channels will evidently be to moderate the rapidity with which the blood would otherwise enter the cranium, and thus preserve the brain from those sudden influxions to which it would otherwise be constantly liable.

(2343.) We must likewise notice a structure, in some respects similar to the above, that exists in the arteries both of the anterior and posterior extremities of the Sloth (*Bradypus*). In these slow-moving animals, the axillary and iliac arteries, just before entering the limbs to which they are respectively destined, suddenly divide into numerous small channels, which again unite into one trunk before the arteries of the member are given off. No doubt such an arrangement will very materially retard the course of the blood as it flows through these multiplied canals, and perhaps is materially connected with the long-enduring strength of muscle that enables these creatures to cling without fatigue to the branches whereby they suspend themselves.

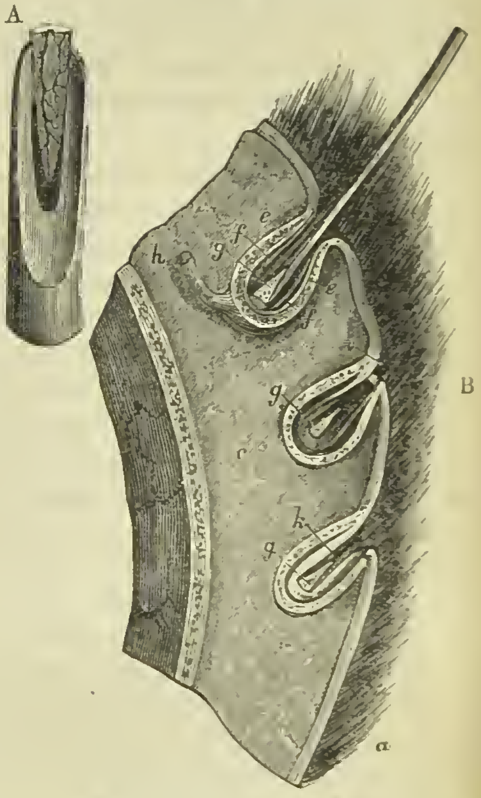
(2344.) Innumerable other minor differences in the course and distribution of the blood-vessels might of course be pointed out, a few of which may require notice elsewhere; but, generally speaking, the arrangement of the vascular system in all quadrupeds is so similar, that the anatomical student who may push his researches thus far will never be at a loss in identifying the different vessels, and comparing them with those found in the human body.

(2345.) Although the respiration of Mammalia is inferior, as regards the extent to which their blood is exposed to the influence of the atmosphere, to the perfection of this process in Birds, nevertheless such is the elevated temperature of the body in these hot-blooded animals, that a warm covering of some non-conducting material is here absolutely requisite to retain the vital warmth, and defend them against the thermometrical changes of the element they inhabit. Their skin is generally, therefore, clothed with a warm covering of hair, a cuticular structure the nature and growth of which it behoves us now to examine. We must first, however, notice the organization of the skin itself; and then the nature of the various structures employed to defend it will be readily understood.

(2346.) The skin of all Mammals, like that of the human body, consists of the *cutis* or vascular true skin, of the *epidermis* or *cuticle*, and of a thin layer of pigment interposed between the two, which is a diversely-coloured secretion deposited, like the cuticle, upon the surface of the cutis.

(2347.) The hairs that cover the quadruped, whatever be their form or thickness, are cylinders of horny or cuticular substance, that grow upon so many minute vascular pulps, from the surface of which the corneous material is perpetually secreted. Some kinds of hair are permanent, and, if constantly cut, will continue to grow during the whole life of the animal; such is the hair of Man, and that which forms the mane and tail of the Horse: but generally the hair is shed at stated periods, to be replaced by a fresh growth. For the most part these structures are so minute, that the apparatus employed in forming them escapes observation; but in very large hairs, such as those that compose the whiskers of the Seal, or of the Lion, it is not difficult to display the organs by which they are secreted. The appended figure, taken from one of the drawings in the Hunterian collection, represents a section of the lip of a young Lion; and in it all the parts connected with the growth of the larger hairs are beautifully displayed. A bulb or sacculus, formed by an inward reflexion of the cutis (fig. 404, B, *c*), and lined by a similar inflexion of the cuticle (*f*), contains in its fundus a vascular pulp (*g g g*), well supplied with large vessels and nerves (*h*). It is from the surface of the pulps (*g*), exhibited upon a magnified scale at A, that the horny stem of the hair is gradually secreted; and its length of course increases in proportion to the accumulation of corneous matter continually added to the root.

Fig. 404.



Section of the lip of a young Lion.
(After Hunter.)

(2348.) Various are the appearances of epidermic appendages in every way analogous to hair both as relates to their composition and mode of growth, and widely different the uses to which they may be converted: the wool of the Sheep, the fur of the Rabbit, the spines of the Hedgehog, the quills of the Porcupine, the scaly covering of the Manis, and even the armour that defends the back of the Armadillo are all of them but modifications of the same structures, adapted to the altered conditions under which the creatures live. Even the horn upon the snout of the Rhinoceros is but an agglomeration of hairy filaments, formed upon a broad and compound pulp. The nails that arm our fingers and toes, the corneous sheath that invests the horns of the Ox and Antelope, nay, the hoofs of herbivorous quadrupeds are all epidermic secretions from the vascular cutis—or, in other words, are hairs, altered in their form and extent according to the exigencies of the case.

(2349.) Widely different, however, are the so-called horns of the Deer tribe, which in reality consist of bone, and, being deciduous, have to be reproduced from year to year by a most peculiar and interesting process. No sooner does the return of genial weather again call forth the dormant reproductive energies of the system, than the budding antlers begin to sprout from the forehead of the Stag, and rapidly expand in their dimensions from day to day. On making a longitudinal section of the young horn, it is found to be continuous with the os frontis, having its outer surface covered with a vascular periosteal membrane derived from the pericranium, which in turn is protected by a fine velvety skin. Moreover, when a growing antler is injected minutely, and its earthy matter removed by means of an acid, vessels derived from the periosteum are found to traverse it in all directions, proving its identity with real bone. As growth goes on, the external carotid arteries, thus called upon rapidly to furnish a prodigious supply of materials, dilate in a remarkable manner, and soon the palm and the antlers of the horn have acquired their full dimensions. No sooner is this accomplished than a prominent ring or *burr* is formed around the base, which, projecting outwards, compresses and soon obliterates the vessels that have hitherto supplied the growing defences. The circulation being thus put a stop to, the soft teguments and periosteum peel off in strips; and the bone, denuded of its covering, becomes a formidable weapon.

(2350.) At the close of the breeding-season the removal of the horns is speedily effected: the connexion between their bases and the os frontis is gradually weakened by interstitial absorption, until at length a slight effort is sufficient to detach the branching honours of the Stag, and they fall off, leaving a broad cicatrix: this soon skins over; and the succeeding year calls forth a repetition of the process*.

(2351.) The CETACEA form a very remarkable group among the hot-blooded Mammifers as relates to the external covering of their bodies.

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* In a physiological point of view this rapid production of osseous matter is truly wonderful. The horns of the Wapiti Deer, thus annually reproduced, will weigh upwards of thirty pounds; and in the fossil Irish Elk the weight of these deciduous defences must have been greater than that of the entire skeleton.

No covering of hair or wool would have been efficient in retaining the vital heat under the circumstances in which these creatures live; and even if such clothing could have been made available, it would have seriously impeded their progress through the water. Another kind of blanket has therefore been adopted:—the cuticle is left perfectly smooth and polished, without any vestige of hair upon its surface; but, beneath the skin, *fat* has been accumulated in prodigious quantities; and, enveloped in this non-conducting material, the Whales are fully prepared to inhabit an aquatic medium, and to maintain their temperature even in the Polar Seas.

(2352.) The skin of all quadrupeds contains innumerable secerning follicles, whereby lubricating fluids are continually furnished for the purpose of maintaining the surface in a moist or supple condition; but not unfrequently these glandular follicles are aggregated together in considerable numbers, so as to form secreting pouches. In many species of Stags and Antelopes, for example, large pouches of this description are found below the margin of the orbit, that furnish a secretion vulgarly regarded as the Stag's "tears." In most instances some of the cutaneous glands secrete a highly odorous material, especially in the vicinity of the parts of generation; and their secretion being most abundant during the rutting season, it is not without reason that these organs are looked upon as destined to attract the sexes, and perhaps to stimulate the sexual passions. The *preputial glands,* so called because they furnish an odoriferous fluid that lubricates the prepuce and glans of the penis in the male, and of the clitoris in the female, are of this kind *. For the most part, these are simple sebaceous follicles contained in the thickness of the prepuce; but occasionally they are replaced by true conglomerate glands, formed of lobes and lobules, and having but a single excretory duct, that opens upon the sides of the *glans penis* or *clitoridis* beneath the prepuce. Many of the Rodentia are furnished with glands of this description, and they are situated on each side of the penis, immediately beneath the skin that covers the pubic region.

(2353.) It is with the preputial glands that we must notice the still more elaborately-developed secreting organs of the Beaver, that furnish the drug called "*castor.*" These organs, represented in the annexed figure (fig. 405), consist of large glandular pouches (*g*, *h*), that discharge their contents in the vicinity of the anal and preputial apertures; but of what importance the material thus abundantly secreted may be in the economy of the animals so provided, it is not easy to conjecture.

(2354.) The secreting apparatus of the Musk Deer (*Moschus moschiferus*), which produces musk, is of analogous conformation. This is an oval pouch situated beneath the skin of the lower part of the belly: its walls are thin, and apparently membranous; but the membrane that lines them is rugose and plicated. The orifice leading to this pouch is small, and opens in front of the prepuce.

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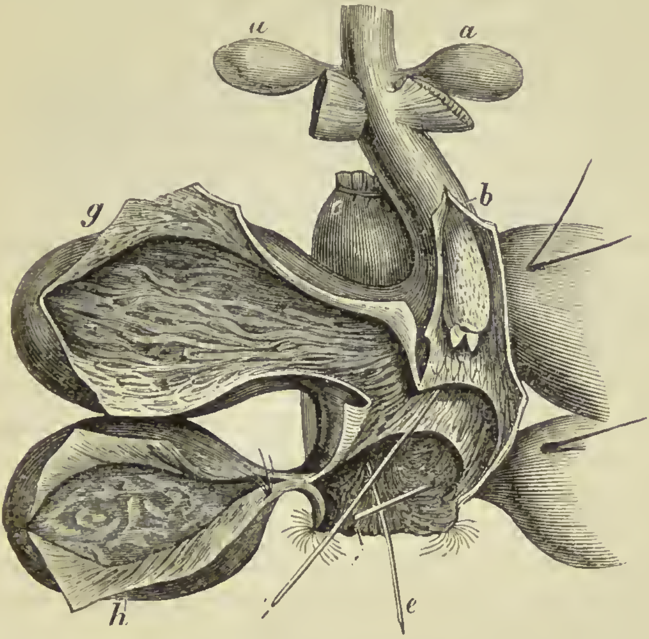
* Cuvier, Leçons d'Anat. Comp. v. p. 252 *et seq.*

Fig. 405.



Sexual organs of male Beaver.

(2355.) Lastly, in connexion with these odoriferous glands we may mention the "temporal glands" of the Elephant, from the duct of which, situated on each side midway between the eye and the ear, there flows a viscid and fetid liquid; and likewise the "*anal glands*" met with in most Carnivora. The ducts of the glands last mentioned open near the margin of the anus; and in some genera, as the Skunk and the Polecat, the stench produced by the fluid poured from these sources is so intolerable as to become a most efficient defence against a foreign enemy.

(2356.) We now come to consider the nervous system of the MAMMALIA, and are of course prepared to anticipate that in proportion as they surpass all other animals in intelligence, so will the encephalic masses assume a complexity and perfection of structure such as we have not hitherto witnessed in the whole series of the animal creation. Their senses likewise may be presumed to have attained the utmost delicacy of organization, in correspondence with the exalted attributes conferred upon this important class, and consequently to exhibit appendages and accessory parts adapting them most accurately to repeat to the sensorium impressions derived from without.

(2357.) Abstruse as the study of the brain has been rendered by the chaotic assemblage of names applied by the earlier anatomists, in their bewilderment, to every definable portion of its substance, we have little doubt that, when the grand laws that have hitherto guided us in investigating the nervous system of the lower animals are had recourse to, the student will soon perceive how little difficulty there is in comparing even the brain of Man with the encephalon of the humbler Vertebrata examined in preceding pages, and thus tracing the progressive advances from simple to more complex organization.

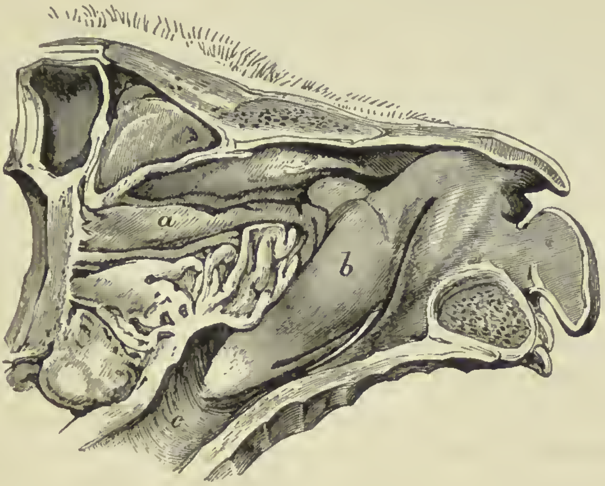
(2358.) The great lessons deducible from all that we have as yet seen relative to the essential organization of the nervous system are obvious enough. First, that all nerves, whether connected with sensation or the movements of the body, emanate from or are in communication with nervous masses called ganglia, which are, in fact, so many brains presiding over the functions attributable to the individual nerves. Secondly, that in the lower animals where these ganglia exist, they are comparatively small, and more or less completely detached from each other; but that in the Vertebrata such is the increased development of the central masses of the nervous system, that they coalesce, as it were, into one great organ called the cerebro-spinal axis; and thus that the encephalon and medulla spinalis are both made up of symmetrical pairs of ganglia appointed to different functions, but so intimately blended together that they are no longer distinguishable, except from the pairs of nerves with which they are connected.

(2359.) Taking the above for axioms (and they are incontrovertible), let us proceed to analyse the cerebro-spinal axis of the Mammalia, and to compare it in simple terms with that of Birds, Reptiles, and Fishes already examined.

(2360.) Commencing at the anterior extremity of the series, the first encephalic masses that present themselves are the "*olfactory nerves*," as the human anatomist has been pleased to call them, although in every one of the details connected with their anatomical structure and relations they confessedly differ from every nerve in the body. They are, in truth, not nerves at all, but brains—the ganglia or brains of smell, from which the olfactory nerves, properly so called, invariably emanate. In Fishes (§ 1802) they were found to equal or even to surpass in size the hemispheres themselves. In Reptiles and Birds they became gradually concealed by the development of the hemispherical masses; and in the Mammalia such is their diminutive appearance, when compared with the *cerebrum*, that they are scarcely recognized as elements of the encephalon at all.

(2361.) In all the oviparous Vertebrata the nerves of smell were two simple cords, one derived from each of the olfactory ganglia, from which they proceeded through osseous canals to the nose. But in the Mammifers these nerves are extremely numerous, in proportion to the extent of the surface to be supplied, and escape from the skull through the cranial plate of the ethmoid bone, which, from the number of apertures that it offers for their passage into the nose, richly merits the name of "cribriform," more especially in the carnivorous quadrupeds possessed of the most acute smell.

Fig. 406.



Olfactory apparatus of the Lion.

(2362.) The interior of the nasal cavity is divided by a median septum into chambers, in each of which a very large surface is produced by the complicated convolutions of the thin nasal plates of the *ethmoid* (fig. 406, *a*), and of the *inferior turbinated bone* (*b*), over which the air is made to pass in its progress to the lungs before it arrives at the posterior nares (*c*). The whole of this complication of bony lamellæ is covered with a delicate and highly-lubricated mucous membrane, wherein the olfactory nerves terminate; and from the figure given, representing the left nasal cavity of a Lion, some idea may be formed of the acuteness of the sense in question conferred upon the predaceous Carnivora.

(2363.) With this perfection of the olfactory sense a corresponding mobility of the outer nostrils is permitted to the Mammiferous races. In the Reptiles and Birds the external apertures leading to the nose were merely immovable perforations in the horny or scaly covering of the upper mandible; but now the nostrils become surrounded with moveable cartilages and appropriate muscles, adapted to dilate or contract the passages leading to the nose, or even to perform more important and unexpected duties, as, for example, in the proboscis of the Elephant.

(2364.) The CETACEA, as regards the conformation of their nostrils, and indeed of the whole of their nasal apparatus, form a remarkable exception to the above description. Inhabiting the water as these creatures do, they are compelled to breathe atmospheric air. Are they, then, to smell through the intervention of an aquatic or aërial medium?

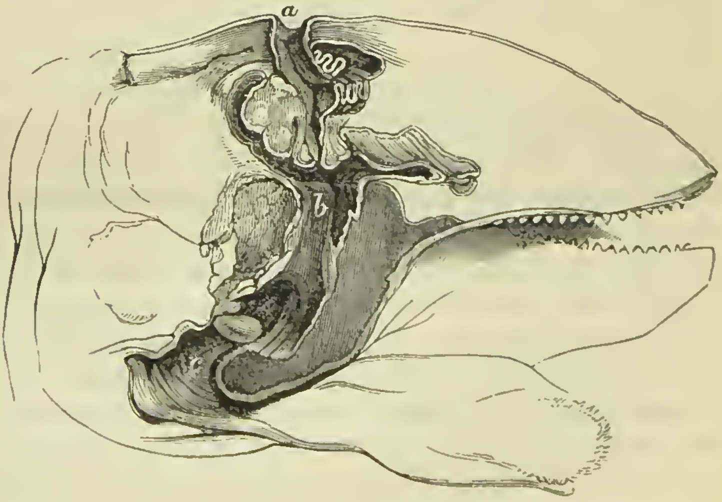
To smell in water would require the nose of a fish, which could not be granted without infringing upon the laws that regulate the progression of animal organization. To smell in air would be useless to the Whale; and moreover its nasal passages are required for another function, with which the exercise of smell would apparently be incompatible.

(2365.) Thus circumstanced, we find the whole nasal apparatus completely metamorphosed, and so disposed as to answer two important purposes: viz. first, to allow the Cetacean to breathe air whilst its mouth is immersed in water; and second, to provide an outlet whereby the water that is necessarily taken into the mouth may escape without being swallowed.

(2366.) The arrangement adopted to attain both these ends is very beautiful. The nostrils, instead of occupying their usual position, are situated quite upon the top of the head (fig. 407, *a*); so that as soon as the vertex reaches the surface, air is freely obtained. But another difficulty remains to be overcome: how is the Cetacean to breathe air while its mouth is full of water?

(2367.) To allow this, the upper extremity of the larynx is prolonged so as to form a thick cartilaginous plug (*c*). When the creature breathes, this elongated larynx is introduced into the posterior nares, as represented in the figure; and, being firmly embraced by a sphincter muscle whilst in that situation, the air is admitted into the trachea through the passages (*a*, *b*), without ever entering the oral cavity.

Fig. 407.



Blowing apparatus of the Porpoise.

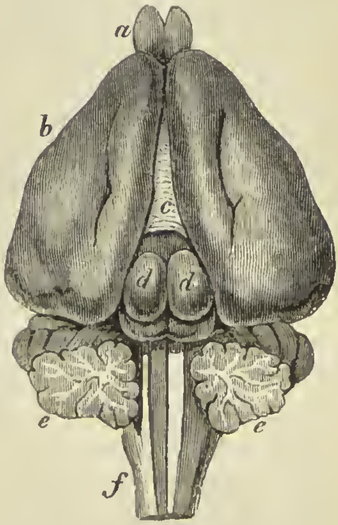
(2368.) It only remains to be seen how the Cetacean gets rid of the water taken into the mouth, without being obliged to swallow it: and the same figure, representing a vertical section of the head of a Porpoise, will enable us to understand the mechanism whereby this is accomplished. The two canals forming the posterior nares (*b*) are defended superiorly by a fleshy valve*, which is closed by means of a very strong muscle placed above the intermaxillary bones. To open this valve the force must be applied from below; and when the valve is shut, all communication is cut off between the posterior nares and the capacious cavities placed above them.

(2369.) These cavities are two large membranous pouches lined with a black skin, which, when they are empty, as represented in the figure, falls into deep folds; but, when full, the walls are distended so as to form capacious oval receptacles. Externally these chambers are enveloped by a very strong expansion of muscular fibres, by which they can be violently compressed.

(2370.) Let us now suppose that the Cetacean has taken into its mouth a quantity of water that it wishes to expel: it moves its tongue and its jaws as though it would swallow; but, at the same time, closing its pharynx, the water is forced upwards through the posterior nares (*b*), till it opens the interposed valve and distends the pouches placed above. Once in these reservoirs, the water may remain there until the creature chooses to expel it, or, in other words, "to blow." In order to do this, the valve between the pouches and the posterior nares being firmly closed, the sacs are forcibly compressed by the muscles that embrace them, and the water is then spouted up through the "blow-holes," or nostrils, to a height corresponding to the violence of the pressure.

(2371.) It must be evident that it would be impossible that a nose, through which salt water is thus continually and violently forced, could be lined with a Schneiderian membrane of sufficient delicacy to be capable of receiving odorous impressions. In the CETACEANS, therefore, the nerves of smell, and even the olfactory lobes of the brain, are totally deficient.

Fig. 408.



Brain of the Rabbit.

(2372.) The second pair of ganglia entering into the composition of the encephalon, and giving origin to nerves, are the optic lobes, from which are derived the nerves of vision. In the Fish and in the Reptile these were at once recognizable as primary elements of the brain; but in the Mammifer, owing to the excessive development of the surrounding parts, they are quite overlapped and concealed by the hemispheres.

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* Cuvier, Leçons d'Anat. Comp. ii. p. 673.

Nevertheless the *tubercula quadrigemina* (fig. 408, *d d*) occupy the same relative position as in the Tortoise (*vide* fig. 348, B, C, *e*), and in like manner still give origin to the nerves appropriated to the instruments of sight, of which they are the proper ganglia.

(2373.) The two optic nerves, before passing to their final destination, partially decussate each other, as in the human subject; they then proceed forward into the orbit, and, penetrating the globe of the eye, expand into the retinæ.

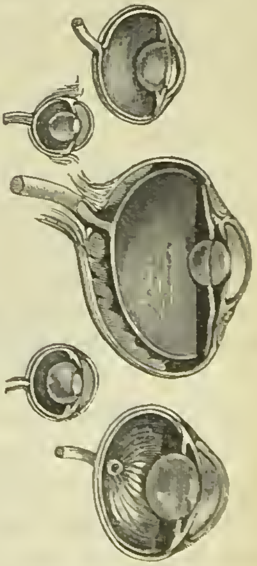
(2374.) Minutely to describe the construction of the eyeball in the Mammalia would be quite superfluous, seeing that in every essential particular it exactly corresponds with that of Man. The disposition of the *sclerotic* and *choroid* coats, the structure of the *cornea*, the arrangement of the *humours* and of the *retina*, the organization of the *iris*—in short, the whole economy of the eye is the same throughout the entire class. Nevertheless there are a few points of secondary importance deserving our attention, whereby the organ is adapted to peculiarities of circumstances in which different tribes are placed.

(2375.) In the Cetacea, and also in the amphibious Carnivora that catch their prey in the water, the shape of the lens is nearly spherical as in Fishes; and the antero-posterior diameter of the eye is in consequence considerably diminished by the extraordinary thickness of the sclerotic at the posterior aspect of the eyeball,—an arrangement approaching very nearly to that already described (§ 1809).

(2376.) Instead of the dark-brown paint which lines the choroid of the human eye, in many Mammals the Ruyschian tunic secretes a pigmentum, of various brilliant hues, that shines with metallic splendour. This membrane, called the "*tapetum*," partially lines the bottom of the eyeball; but its use has not as yet been satisfactorily pointed out.

(2377.) The shape of the pupil likewise varies in different quadrupeds: for the most part, indeed, the pupillary aperture is round, as it is in Man; but in Ruminants, and many other Herbivora, it is transversely oblong. In the Cats (*Felidæ*), that hunt in the gloom, and consequently require every ray of light that can be made available, the pupil is a long vertical fissure: but this only obtains among the smaller genera; for in those Feline Carnivora that surpass the Ocelot in size, such as the Leopard, the Lion, and the Tiger, the pupil again assumes a round form.

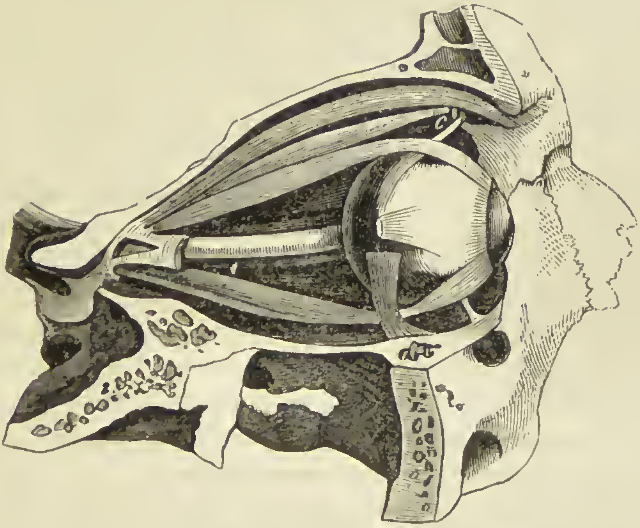
Fig. 409.



Structure of the eye.

(2378.) The eyes of Mammalia are lodged in bony orbits, as in the oviparous Vertebrata, and in like manner are supported in their movements by a quantity of semifluid fat, with which the orbital cavities are filled up. In Man, as in Birds, Reptiles, and Fishes, six muscles are appropriated to the movements of each eyeball, viz. four *recti* and two *obliqui*. The four *recti* muscles have the same disposition in Mammalia as in Birds; that is, they arise from the margin of the optic foramen, and run forward to be inserted opposite to each other upon the superior, inferior, and lateral surfaces of the sclerotic coat. The *inferior oblique* likewise offers a similar arrangement in all the Vertebrata, arising from the margin of the internal wall of the orbit, and running outwards to be attached to the external surface of the globe of the eye. But the *superior oblique*, in the class before us, takes a very peculiar course. Arising like the rest, it passes forward to the upper and inner margin of the orbit, where its tendon is reflected over a little cartilaginous pulley (fig. 410, *c*), and turns back again to be inserted into the external and posterior aspect of the eyeball.

Fig. 410.



Muscles of the eyeball.

(2379.) In addition to the six muscles appointed for the movements of the eye in Man and the Quadrumana, other Mammalia have a seventh, called the *choanoid* or *funnel-shaped* muscle. This likewise arises from the borders of the optic foramen, and, gradually expanding, forms a hollow cone interposed between the *recti muscles* and the *optic nerve*, the base of the cone being attached to the sclerotic behind the insertion of the recti. Frequently, indeed, this *choanoid* or *suspensory muscle* is divided into four portions, in which case the animals so provided would seem to have eight recti muscles.

(2380.) The eyelids of Mammalia resemble the human in every respect, excepting that in the lower orders a remnant of the nictitating membrane is still met with; but it is of small dimensions, and unprovided with muscles.

(2381.) The lacrymal apparatus exists in all quadrupeds; and the lacrymal gland occupies the same situation as in Man, the tears being poured on to the conjunctiva near the external canthus of the eyelids. The lacrymal ducts, likewise, whereby the tears are conveyed into the nose, so nearly resemble the human as to require no particular description. The *carunculæ lacrymales* are also met with at the inner canthus of the eyelids. In some quadrupeds, indeed, an additional gland exists, called the *glandula Harderi*; this is situated behind the internal angle of the eye, and secretes a lubricating fluid, that is discharged beneath the rudiment of the third or nictitating eyelid.

(2382.) In Whales, as might be expected from their aquatic habits, no vestige of a lacrymal apparatus is to be seen.

(2383.) Behind the *optic lobes* of the encephalon the nervous centres, from whence the other cerebral nerves take their origin, are so intimately blended together that the anatomist is no longer able to distinguish them from each other. They form, in fact, the "*medulla oblongata*," and are the commencement of that long series of sentient and of motor ganglia that forms the spinal cord.

(2384.) All the nerves derived from the medulla oblongata and from the spinal cord are throughout the Mammiferous class exactly comparable to those met with in our own species, and therefore will require but brief notice.

(2385.) The *third, fourth,* and *sixth* pairs are destined to the muscles of the eye, and their distribution is the same as in Man.

(2386.) The *fifth* pair, or *trigeminal* nerves, consist of both motor and sentient fasciculi, both of which are distributed to the different parts of the face exactly as in the human subject, allowance of course being made for the varying form of the jaws, and for the proportionate size of the different organs connected with mastication.

(2387.) The *seventh,* or facial nerve, as also the *glosso-pharyngeal*, the *pneumogastric,* and the *lingual,* have the same origin and general distribution throughout the whole class.

(2388.) The eighth pair of nerves are here, as in all the Vertebrata, devoted to the sense of hearing, which in the Mammifera attains its highest development and perfection. The sensitive portion of the auditory apparatus, or the internal ear, is now enclosed in the petrous portion of the temporal bone, and imbedded in osseous substance of such stony hardness that, except in very young subjects, it is by no means easy to display its different parts.

(2389.) As in Fishes and Reptiles, it consists of several membranous chambers or canals, filled with a limpid fluid, over which the filaments of the auditory nerve spread out. The whole apparatus, indeed, except in its proportionate size, very accurately resembles the auditory organ of the lower Vertebrata. The *semicircular canals* exhibit nearly the same arrangement, and in like manner communicate with the *vestibule* by five orifices. The vestibule itself is small, and no longer contains any chalky concretions: it communicates on the one hand with the cavity of the tympanum, by means of the foramen ovale; and on the other sends off a canal (*scala*) to form the *cochlea*, an organ which in the Mammifer assumes its full development and perfection.

(2390.) In Reptiles and Birds, as the reader will remember, the *cochlea* was a simple canal bent upon itself (fig. 367, *e*), one end of which (*scala vestibuli*) opened into the vestibule, while the other (*scala tympani*) terminated at the tympanic cavity, from which it was separated by the membrane of the fenestra rotunda; but in the Mammalia the two scalæ of the cochlea are considerably elongated, and wind in a spiral direction around a central axis (*modiolus*), so as very accurately to resemble the whorls in the shell of a snail, whence the name of the organ is derived *.

(2391.) It is in the increased complexity of the cochlea, therefore, that the chief character of the labyrinth of the Mammal consists. But in the tympanic cavity the differences between the Mammiferous ear and that of the Bird are still more striking and decided.

(2392.) The cavity of the tympanum in the class before us is very extensive, and not unfrequently its extent is considerably enlarged by the addition of capacious mastoid cells. By means of the Eustachian tube it communicates freely with the throat. Upon its inner wall it offers the *fenestra ovalis* and the *fenestra rotunda*, closed by their respective membranes; and externally is the *membrana tympani*, the vibrations of which are to be conveyed to the labyrinth.

(2393.) In Reptiles and Birds the communication between the drum of the ear and the membrane of the fenestra ovalis was effected by the interposition of a single ossicle, called the "*columnella*;" but in Mammals a chain of four ossicles, named respectively the *malleus*, the *incus*, the *os orbiculare*, and the *stapes*, intervenes between the labyrinth and the membrana tympani: these ossicles, both in their disposition and connexions, are precisely similar to those of Man, and, moreover, are acted upon by little muscles in every respect comparable to those of the human subject.

(2394.) However remote the structure of the tympanic chain of ossicles in the Mammal may appear to be from that of the simple columnella of the Bird, it is interesting to see how gradually the transition is effected from one class to another even in this particular of their economy; for in the Ornithorhynchus, the Echidna, and the Kangaroo, so bird-like is the form of the *stapes*, that it might easily be mistaken for the ossicle of one of the feathered tribes *, and every intermediate shape is met with as we advance from this point towards the stirrup-shaped bone of the most perfect quadrupeds.

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* In Man, and by far the greater number of Mammals, the scalæ of the cochlea make two turns and a half around the modiolus; but in a few Rodent quadrupeds, as for example in the Guinea Pig, the Cavy, and the Porcupine, there are as many as three turns and a half.

(2395.) It is in the class under consideration that for the first time an external ear properly so called makes its appearance; for the feathered appendages of the Owl or of the Bustard (§ 2089) are scarcely entitled to such an appellation. In the Mammifera, however, with a very few exceptions, such as the Cetacea, Moles, and the Seal tribe, a moveable cartilaginous *concha* is appended to the exterior of the head, adapted by its form and mobility to collect the pulses of sound and convey them inwards towards the drum of the ear. The basis of this external auricle is composed of fibro-cartilage covered with a delicate skin, and its cavity is moulded into various sinuosities, so disposed, no doubt, as to concentrate sonorous impressions. In Man, as the anatomist is aware, numerous small muscles act upon the auricular cartilages; but in quadrupeds possessed of moveable ears the number and size of these muscles are prodigiously increased, and the ears are thus directed with facility in any required direction.

(2396.) More minutely to describe the structure of the auditory apparatus in the Mammiferous class would be foreign to our present purpose; nevertheless we must not omit to notice one most remarkable provision whereby the Whales, strangely circumstanced as those creatures are, are permitted to hear either through the medium of the air they breathe, or of the water in which they pass their lives. The reader will at once appreciate the difficulties of the case: the ear of a fish, without any external communication, although best adapted to receive the stunning concussions conveyed through the denser element, could never appreciate the more delicate vibrations of the air; and the ordinary Mammiferous ear would be perpetually deafened by the thundering of the water. How is the Whale to hear what is going on in either the sea or the atmosphere?

(2397.) The plan adopted is simple and efficacious:—The external meatus of the ear is reduced to the smallest possible diameter, the canal being barely wide enough to admit a small probe: this is the hydrophonic apparatus, and is all that is exposed for the reception of aquatic sounds. The Eustachian tube, on the contrary, is very large, and opens into the blow-hole through which the Whale respires atmospheric air: if, therefore, the Cetacean comes to the top of the water to breathe, it is the Eustachian tube that conveys aërial sounds to the ear. And thus it hears sufficiently under both conditions.

(2398.) So far, as the student will have perceived, the different portions of the encephalon to which we have adverted correspond most exactly to similar parts met with even in the brain of a reptile. Where, then, are we to look for those grand differences whereby the Mammiferous brain is peculiarly characterized? The peculiarities of the brain of a Mammal are entirely due, first, to the increased proportional development of the cerebral hemispheres; and secondly, to the existence of lateral cerebellic lobes, in connexion with both of which additional structures become requisite.

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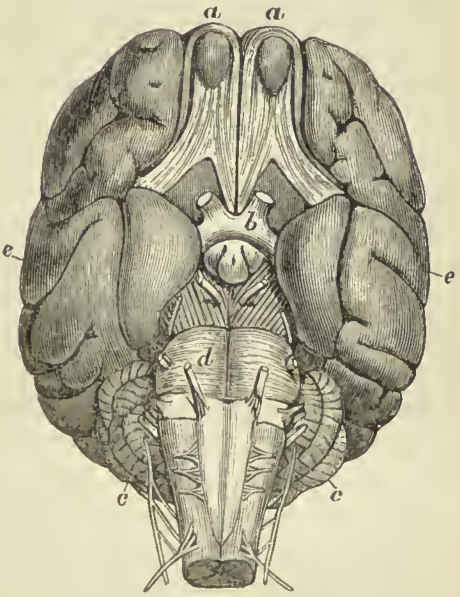
* *Vide* Sir Anthony Carlisle "On the Physiology of the *Stapes*." Phil. Trans. for 1805.

(2399.) In those Marsupial tribes that form the connecting links between the Oviparous and Placental Vertebrata, the brain still exhibits a conformation nearly allied to that of the Bird, and the great commissures required in the more perfect encephalon are even yet deficient; but in the simplest brain of a Placental Mammifer the characteristic differences are at once apparent.

(2400.) In the Rabbit, for example (fig. 408), the cerebral hemispheres (*b*) are found very materially to have increased in their proportionate dimensions; and although, even yet, convolutions upon the surface of the cerebrum are scarcely indicated, additional means of intercommunication between the hemispheric masses become indispensable. The *corpus callosum*, therefore, or *great transverse commissure* of the hemispheres (fig. 408, *c*), is now superadded to those previously in existence; while other medullary layers, called by various ridiculous names, bring into unison remote portions of the cerebral lobes.

Fig. 411.



Brain of the Lion.

(2401.) In proportion as intelligence advances, the surface of the cerebral hemispheres, becoming more extensive, is thrown into numerous convolutions separated by deep sulci; until at length in the Carnivora, as, for instance, in the Lion (fig. 411), the cerebrum (*e e*) attains such enormous dimensions that the other elements of the encephalon are, as it were, hidden among its folds.

(2402.) But, in addition to this increased complexity of the *cerebrum*, the *cerebellum* likewise has assumed a proportionate importance. In the Oviparous races this important element of the brain consisted only of the mesial portion, so that no cerebellic commissure was requisite: but in the Mammal it exhibits in addition two large lateral lobes (fig. 411, *c c*); and coexistent with these the *pons Varolii* (*d*) makes its appearance, embracing the medulla oblongata and uniting the opposite sides of the cerebellum.

(2403.) The structure of the *spinal cord* and the origins of the spinal nerves throughout all the Mammalia are precisely similar, and exactly correspond with what occurs in the human body; neither does the anatomical distribution of the individual nerves derived from this source require any special notice, since, generally speaking, it differs in no important particular from the arrangement with which every anatomist is familiar.

(2404.) The sense of touch in Mammalia is diffused over the whole surface of the body,—its perfection in different parts being of course influenced by the nature of the integument, and the number of sentient nerves appropriated to any given region. All the nerves derived from the sensitive tract of the spinal medulla, and the three divisions of the fifth pair of encephalic nerves, are equally susceptible of tactile impressions; so that, in a class so extensively distributed as that before us, we need not be surprised to find a special apparatus of touch developed in very different and remote parts adapted to particular exigencies. Thus the whiskers of the Seal and of nocturnal Carnivora, the lips of the Horse, the trunk of the Elephant, the hands of Man, the hind feet of the Quadrumana, and even the extremity of the tail where that organ is prehensile, are all in turn made available as tactile instruments, and exercise the sense in question with the utmost delicacy.

(2405.) In the Bats, where the sense of vision becomes inadequate to guide them through the dark recesses where they lurk, that of touch assumes its utmost development, and every part of the body that could by possibility be furnished with it has been abundantly provided for in this respect. Not only is the broad expanse of the wing acutely sensible, but the very ears have been converted into delicate feelers; nay, from the tip of the nose in some species, membranes of equal sensibility have been largely developed; so that the Bats, as was ascertained by Spallanzani, even when deprived of sight and hearing, will fly fearlessly along, and avoid every obstacle with wonderful precision, guided apparently by the sense of touch alone.

(2406.) The sympathetic system of the Mammifera differs in no important particular from the human, the arrangement of the ganglia and the distribution of the plexuses being in all respects the same.

(2407.) In the conformation of the genito-urinary apparatus in Mammalia the physiologist will find many circumstances of extreme interest.

(2408.) Even in Birds, as the reader will remember, the secretions of the testes and of the kidneys were both poured into the common cavity of the cloaca, and discharged through the anal orifice. No bladder was provided for the reception of the urine; and a simple, grooved, but imperforate penis, even where that organ was most fully developed, was sufficient for the purpose of impregnation.

(2409.) Widely different, however, is the arrangement of the male genito-urinary system in the class we are now considering. The cloacal cavity is no longer met with, the terminations of the rectum and of the sexual ducts being now remotely separated; the penis is traversed by a complete urethral canal, through which the seminal fluid is forcibly ejaculated; and moreover, subsidiary glands not met with in any of tho preceding classes add their secretions to that of the testes, and thus facilitate the intromission of the fecundating fluid. A urinary bladder is now superadded to the renal apparatus, wherein the urine is permitted to accumulate in considerable quantities, prior to its expulsion through the urethra—the excretory duct common to both the urinary and generative organs.

(2410.) Not less remarkable are the corresponding changes observable in the disposition of the female reproductive organs. The Mammifers are appointed to bring forth living young; a uterine receptacle is therefore necessarily provided for the reception of the fœtus, and mammary glands are given to support the tender offspring during the earlier portion of its existence. But the history of these organs cannot be laid before the reader at a glance, and we must therefore patiently trace out their development step by step, and gradually ascend from the Oviparous type up to the most complete forms of the genito-urinary system.

(2411.) Commencing with the urinary apparatus, the first parts that offer themselves to our notice are the kidneys, the ureters, and the bladder, in describing which the same remarks will be found applicable to both sexes.

(2412.) The *kidneys* in all the Mammiferous orders occupy a similar position, being situated in the loins, on each side of the aorta, from whence they receive a copious supply of arterial blood by the renal arteries, which, after having supplied the urinary secretion, is returned to the circulation by the *emulgent veins* that empty themselves into the *inferior cava.*

(2413.) As relates to their intimate structure, the kidneys of all quadrupeds are essentially similar to those of our own species, each of these organs being composed of uriniferous tubules of extreme tenuity that terminate in central papillæ from which the urine flows. These tubules, as they advance into the medullary substance of the kidney, bifurcate again and again, until they arrive at the cortical or external portion, where they spread out on all sides, and, becoming exceedingly flexuous, are inextricably intervolved among each other, so that the entire cortex is composed of their gyrations. At last all the uriniferous vessels terminate in blind extremities, and, according to Müller*, have no immediate communication with the vascular system.

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* De Glandularum Structurâ, p. 102.

(2414.) In form the kidneys of Mammals more or less resemble the human; but there is one important circumstance observable in many tribes, which is well calculated to show that these organs, even when they appear most simple, are in reality formed by the coalescence of several distinct glands. In the human fœtus the kidneys present a lobulated appearance; that is to say, they are evidently composed of numerous divisions, each having the same structure; but in the adult the lines of demarcation between these lobes become entirely obliterated. In many genera, however, this division into lobes remains permanent during the whole lifetime of the creature: such, for example, is remarkably the case in amphibious Carnivora, as the Otter and the Seal tribes, and still more strikingly in the Cetaceans, where the kidneys are not inaptly comparable to large bunches of grapes. But whatever the form of the organ, or the number of lobules entering into its composition, the urine secreted by each kidney is received into a common excretory duct called the *ureter*, and is thus conveyed into the *bladder* prepared for its reception.

(2415.) The urinary bladder exists in all the Mammalia, and receives the ureters by valvular orifices in precisely the same manner as in the human subject. In the male its excretory duct, the urethra, is common to the urinary and generative systems, and terminates at the extremity of the penis; but in the female the urethral canal is of much simpler structure, opening by a distinct orifice into the vulva *.

(2416.) We have preferred laying before the reader the above general view of the urinary system of Mammalia to noticing in detail those varieties that occur in the disposition of the bladder and urethra of some of the lower tribes, in conformity with the different types of organization presented by their sexual organs; these, however, must not be lost sight of in following out the development of the reproductive apparatus, from the oviparous races to the most perfect and highly-gifted members of the animal creation. It is to this important subject that we must now invite the attention of the reader.

(2417.) The oviparous Vertebrata lay eggs, and their young are perfected without further nourishment derived from the maternal system than is contained within the egg itself. In our own species, and throughout all the races of Mammalia found on the European continent, the females produce their young alive and fully formed, capable of independent existence, but, nevertheless, nourished for a considerable period by milk derived from the breast of the mother. The distinction, therefore, between an oviparous and a viviparous creature would appear to be sufficiently broad, and the physiological relations between them as remote as possible.

(2418.) The student, however, who has followed us thus far through the long series of living beings that have successively presented themselves to our notice must naturally expect that, between animals so dissimilar in their economy as the Bird and the Mammal, intermediate types of organization must occur, and that the transition from one to the other is here, as elsewhere, gradually accomplished.

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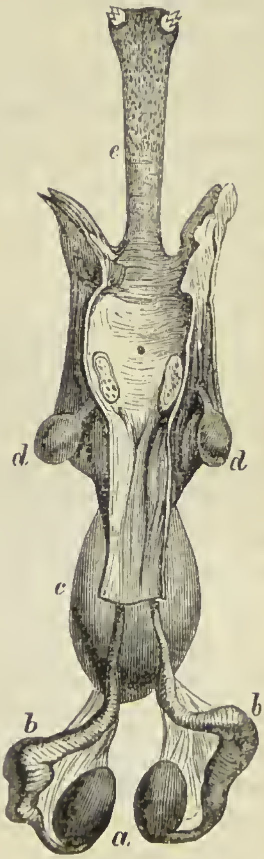
* The Lemur and the Mole form remarkable exceptions; for in these creatures the female urethra traverses the clitoris precisely as in the other sex.

(2419.) In this respect his expectations will be by no means disappointed. The *Ornithorhynchus paradoxus* and the *Echidna,* animals met with only in the continent of New Holland, are most obviously connecting links between these two grand classes; and, therefore, it is with the history of these strange animals that we must commence our examination of the Mammiferous generative system.

(2420.) The *Ornithorhynchus paradoxus* well deserves the specific epithet applied to it by zoologists. It has, indeed, the form of a quadruped, and its body is covered with hair, and not with feathers; but its mouth is the beak of a duck; and upon its hind feet, which are broadly webbed, the male carries a spur not unlike that of a barn-door fowl. Having the beak of a bird, how is the creature to suck? Nevertheless the females have mammary glands well developed, but destitute of prominent nipples; so that the mode in which the young animal obtains the milk provided for it is even yet a puzzling question. Does the Ornithorhynchus lay eggs? or produce living young ones? This is a query that has not been satisfactorily answered; and its generative apparatus is so nearly related to that of an oviparous animal that even anatomy throws but little light upon the subject.

(2421.) Both in the male and female there is, in fact, but one vent, that leads to a cloacal chamber resembling that of a bird; and the entire organization of the sexual organs is rather that of an egg-laying than of a viviparous creature, as will be evident from the following details respecting them.

Fig. 412.



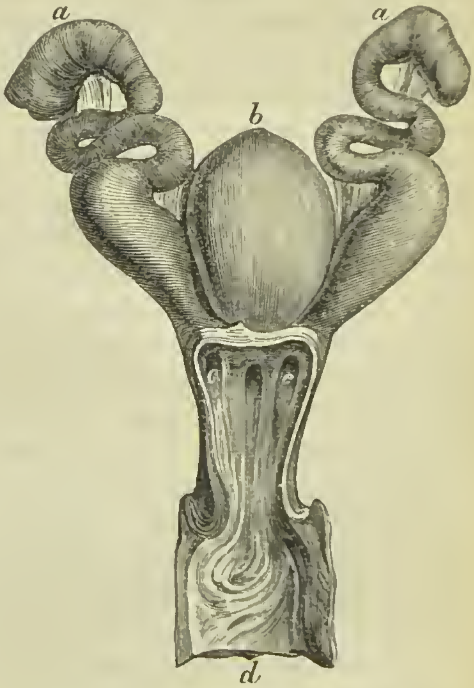
Male generative organs of *Ornithorhynchus paradoxus.*

(2422.) The penis of the male *Ornithorhynchus is perforated by a urethral canal, through which the semen passes, but not the urine*; its extremity, moreover, is terminated by two tubercles, giving it almost a bifid appearance. This penis, when in a relaxed state, is lodged in a little pouch in the floor of the cloaca, from which it projects when erected.

(2423.) The cloacal cavity, as in birds, gives passage to the fæces and to the urine. The testes (fig. 412, *a*) and the vasa deferentia (*b*) resemble those of an oviparous animal; but, on the other hand, there is a complete urinary bladder (*c*), and moreover a pair of auxiliary (*Cowper's*) glands (*d d*), organs never met with except in the Mammiferous class.

(2424.) The anatomy of the female organs is not less singular. The ovaria (fig. 414, *a a*) are large and racemose, like those of a bird; while the two *oviducts* or *uteri* (fig. 413, *a a*), as the reader may choose to call them, open into the cloaca by two distinct orifices (*c c*), situated on each side of the urethra, derived from the bladder (*b*).

Fig. 413.



Generative organs of female *Ornithorhynchus*.

(2425.) It is to Professor Owen that science is indebted for all that is known relative to the anatomy of the female Ornithorhynchus when in a gravid state; and his researches upon this subject appear to establish the following interesting particulars:—First, that the ovaria, notwithstanding their racemose appearance, exhibit all the essential characters of the Mammiferous type of structure; and *corpora lutea* were formed where the reproductive germs had escaped from them. Secondly, that the eggs contained in the uterine cavities (fig. 414, *c, e*) had no connexion whatever with the walls of the uterus. Thirdly, that each ovum exhibited the usual parts of an egg. viz. the cortical membrane, the albumen, and the yelk: and that upon the latter a *membrana vitelli* and the *blastoderm* or germinative membrane were plainly perceptible. Fourthly, that the uterine walls assume an increased thickness when in an impregnated state, but that not the slightest trace of a decidual or adventitious membrane is apparent in the cavity of the womb. From all these circumstances, the distinguished author of the paper referred to* was led to adopt the subjoined train of reasoning as to the probability of the Ornithorhynchus being a viviparous mammal. The form, the structure, and the detached condition of the ova, observes Professor Owen, may still be regarded as compatible with, and perhaps favourable to, the opinion that they are excluded as such, and that the embryo is developed out of the parent's body. But the following objections present themselves to this conclusion:—The only part of the efferent tube of the generative apparatus which can be compared in structure or relative position with the shell-secreting uterus of the Fowl is the dilated terminal cavity in which, in all the specimens examined, the ova were situated: and upon the oviparous theory it must be supposed either that the parietes of this cavity, after having secreted the requisite quantity of soft material, suddenly assume a new function, and complete the ovum by providing it with the calcareous covering necessary to enable it to sustain the superincumbent weight of the mother during incubation; or that this is effected by a rapid deposition from the cuticular surface of the external passages; or lastly, according to a more recent but still more improbable supposition, by a calcareous secretion of the abdominal glands poured out upon the ovum after its exclusion.

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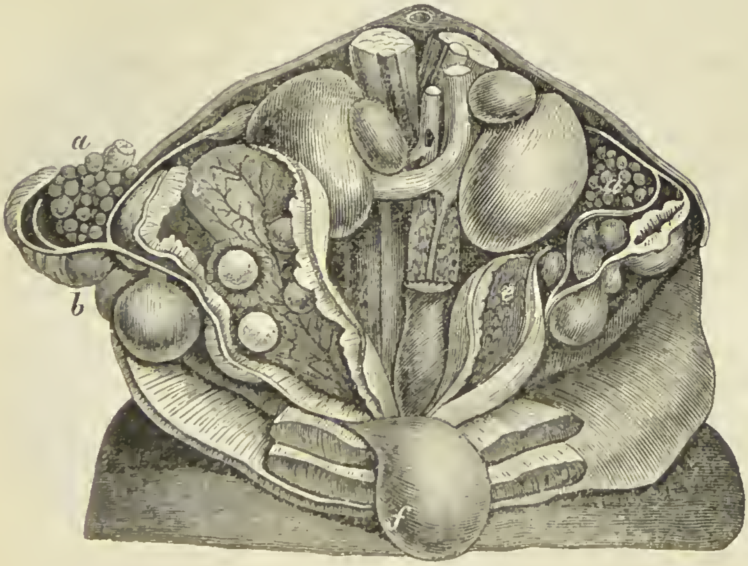
* "On the Ova of the *Ornithorhynchus paradoxus*," by Richard Owen, Esq., Phil. Trans. pt. ii. for 1834, p. 563.

Fig. 414*.



Ovaria of *Ornithorhynchus paradoxus.*

(2426.) But granting that the egg is provided in any of these ways with the necessary external covering, yet, from the evidence afforded by the specimens examined, the ovum is deficient in those parts of its organization which appear to be essential to successful incubation, viz. a voluminous yelk to support the germinal membrane, and the mechanism for bringing the cicatricula into contiguity with the body of the parent. Add to this, that such a mode of development of the fœtus requires that all the necessary nutritive material be accumulated in the ovum prior to its exclusion. Now the bony pelvis of the Bird is expressly modified to allow of the escape of an egg, both large from the quantity of its contents, and unyielding from its necessary defensive covering: but, whatever affinities of structure may exist in other parts of the Ornithorhynchus, it is most important to the question of its generation to bear in mind that it manifests no resemblance to the Bird in the disposition of its pubic bones.

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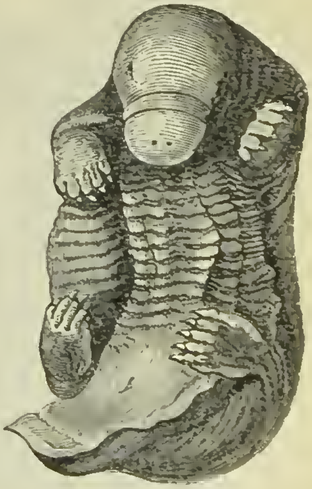
* Owing to an error on the part of the draughtsman, who has neglected to reverse the drawing, the left uterus in the above figure is represented on the right side, and *vice versâ.*

(2427.) From the above considerations it is therefore probable that the young Ornithorhynchi are produced alive; yet still the reader will perceive, by the closeness of the reasoning brought to bear upon the subject, how nearly the oviparous and mammiferous modes of generation are approximated by the interposition of these connecting forms of Vertebrata.

(2428.) But if from these arguments, derived from the anatomical construction of the female parts, it is allowable to conjecture that the Ornithorhynchus is ovoviviparous (using that term in a strictly philosophical sense), the difficulties of the case are by no means removed; and granting that the contents of the ovum are barely sufficient to nourish the embryo during the very earliest stages of its development, we have yet to learn how the fœtus is matured after the exhaustion of this supply. There is no reason whatever to suppose that a placenta exists at any period of uterine gestation; neither is there a marsupial pouch in which the prematurely-born young can be carried about and supplied with milk; so that, whether the young Monotreme be developed in the uterus or out of the uterus, we are equally at a loss to understand how its nutrition is provided for.

Fig. 415.



Young *Ornithorhynchus*.

(2429.) In this state of uncertainty, the anatomy of the young Ornithorynchus, examined at as early a period as possible, becomes a subject of extreme interest; and fortunately Professor Owen has been enabled to add observations upon this subject to his other valuable researches relative to the generation of these creatures*. The annexed figure (fig. 415) is a portrait of one of the specimens dissected; and from every appearance it could not have been more than a few days old—that is, supposing it to have been born at an advanced period of its development. It was as yet blind; and the situation of the eyes was only indicated by the convergence of a few wrinkles to one point; but when these were put upon the stretch, the integument was found entire, and completely shrouding or covering the eyeball anteriorly: its skeleton, moreover, was quite in a cartilaginous condition; and it was obviously in every respect helpless, and still dependent upon its mother for sustenance.

(2430.) The stomach was found filled with *milk*—a sufficient proof that at that period, at least, it was nourished by the lacteal secretion; but with regard to its previous fœtal condition, the difficulties that have been above alluded to remained in their full force. No trace of an umbilical cicatrix was visible upon the ventral surface of the body, even when examined with a lens,—a sure proof that no placenta had existed. The ilium was carefully examined, but there was no appearance of the pedicle of the vitelline vesicle; nevertheless the other vestiges of fœtal organization were more obvious than in the ordinary marsupial or ovoviviparous Mammalia. The umbilical vein was seen extending from a linear cicatrix of the peritoneum, opposite the middle of the abdomen, along the anterior margin of the suspensory ligament to the liver. It was reduced to a mere filamentary tube filled with coagulum. From the same cicatrix the remains of the umbilical arteries extended downwards, and near the urinary bladder were contained within a duplicature of peritoneum, having between them a small flat oval vesicle, the remains of an *allantois*, which was attached by a contracted pedicle to the fundus of the bladder; but still, as both the embryo of the Bird and that of the ovoviviparous Reptile have an allantois and umbilical vessels developed, no certain inference can be drawn from the above appearances as to the oviparous or viviparous nature of the generation of the Ornithorhynchus.

(2431.) Such is the present state of our knowledge relative to the first type of Mammiferous generation, viz. that met with among the MONOTREMATA. In the second, or MARSUPIAL TYPE, the phenomena, although equally strange, are better understood; and to those we must now beg the attention of the student.

(2432.) The MARSUPIALIA, from the variety of their forms and extensive distribution, constitute a most important section of Mammiferous quadrupeds, distinguished by the peculiarities that occur in the organization of their generative apparatus and by the singular mode in which they produce and suckle their young. Animals of this kind are only met with in the American and Australian regions of our globe; and so widely do they differ, as far as their reproduction is concerned, from all the Mammiferous inhabitants of the Old World, that they might even be regarded as forming quite a distinct and separate group in the animal creation, serving to accomplish another step in that grand transition by which the physiologist is conducted from the oviparous to the placental Vertebrata.

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* Owen on the Young of the *Ornithorhynchus paradoxus*, Trans. Zool. Soc. vol. i.

(2433.) The Marsupialia are, strictly speaking, *ovoviviparous*; that is to say, the uterine ovum never forms any vascular connexion with the maternal system, but after a very brief intra-uterine gestation the embryo is expelled in a very rudimentary and imperfect condition, even its extremities being as yet but partially developed; and in this helpless state the fœtus is conveyed from the uterus into a pouch or *marsupium*, formed by the integument of the abdomen, there to be nourished by milk sucked from the mammary glands, until it arrives at such a state of maturity as enables it to assume an independent existence.

(2434.) We may naturally expect, therefore, that, with habits so remarkable, the structure of the generative apparatus, both in the male and female Marsupial, will offer important peculiarities; and these accordingly first present themselves for description.

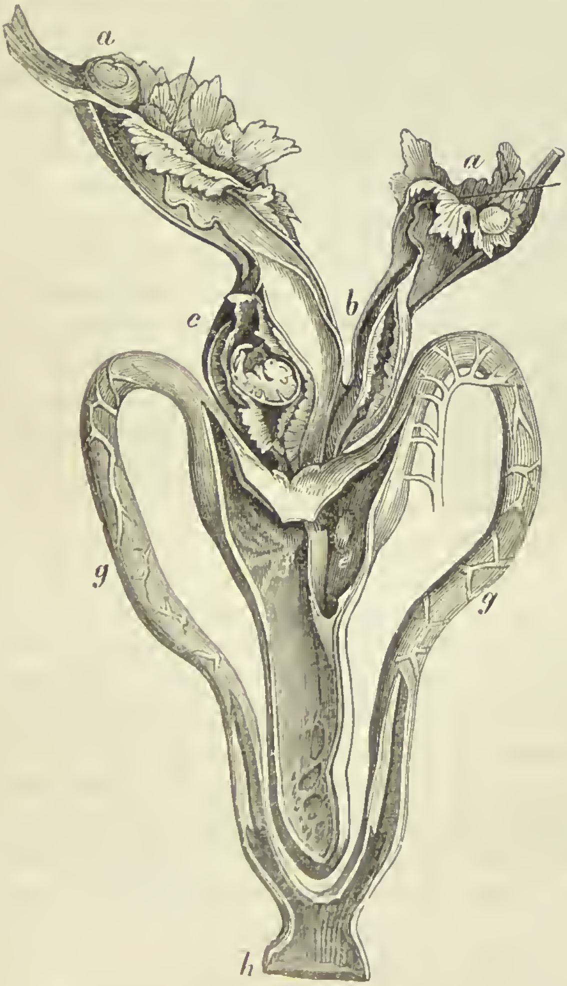
(2435.) We select the Kangaroo as an example of the entire group, beginning, as we have hitherto done, with the organization of the male organs of generation.

(2436.) The first circumstance that strikes the attention of the anatomist in a male Marsupial is the extraordinary position of the testes, which, instead of being situated behind the penis, as in most placental Mammals, are placed in front of that organ in a kind of scrotum that occupies the same place as the pouch of the female, and is in like manner supported by two *marsupial bones* derived from the pubes, around which the cremaster muscle winds in such a manner as to enable it powerfully to compress the testicles during the congress of the sexes. The vasa deferentia derived from the testes open into the commencement of the urethra, which now, for the first time, forms a complete canal leading from the bladder to the extremity of the penis. The auxiliary glands that pour additional secretions into the urethra are of great size, and more numerous than those met with in the human subject. In the first place, the commencement of the urethral tube is embraced by a bulky and conical *prostate*, to which succeed three pairs of large secreting organs (*Cowper's glands*), each enveloped in a musculo-membranous sheath, apparently intended to compress their substance, and thus efficiently discharge their secretion into the canal of the urethra, there to be mixed up with the seminal fluid.

(2437.) But perhaps the most decided peculiarities that characterize the males of Marsupial quadrupeds are met with in the construction of the penis itself. The two roots or *crura* of the *corpora cavernosa* are not, as in the higher Mammals, attached to the branches of the ischium by ligamentous bands, but each swells into a large bulb enclosed in a powerful muscular envelope. The bulbous portion of the urethra is likewise double, and embraced by powerful muscles. In the Kangaroo, moreover, the spongy erectile tissue that encloses the urethra passes with that canal through the centre of the body of the penis, formed by the corpora cavernosa, so that a *glans* can scarcely be said to exist; but in other Marsupials, as, for example, in the Opossums (*Didelphys*), the extremity of the intromittent organ is bifid, thus forming another approximation to the oviparous type.

(2438.) In the female Kangaroo, and other Marsupials, there are still two distinct uteri, opening into the vagina by distinct orifices; and even the vagina itself is double, exhibiting a very peculiar and interesting arrangement, represented in the subjoined figure (fig. 416). The ovaria

Fig. 416.



Generative organs of the female Kangaroo.

(*a a*) are now reduced to comparatively small dimensions when compared with those of the Ovipara—a circumstance that depends upon the reduced size of the ovarian ovules, which no longer present the bulky yelks peculiar to oviparous generation, the necessity for the existence of such a large store of food being now superseded by the provision of another kind of nourishment derived from the mammary glands. The Fallopian tubes commence by wide fimbriated apertures; and each leads into a separate uterine canal (*b*, *c*), in which the first part of gestation is accomplished. The two uteri open by two orifices (*e*, *f*) into the two vaginæ (*g g*), which remain quite distinct from each other from their commencement to their termination in the *urethro-sexual canal* (*h*)—a kind of cloaca into which both the vaginæ and the urethra empty themselves.

(2439.) Such being the arrangement of the generative apparatus of the female Kangaroo, we are prepared, in the next place, to consider the structure of the Marsupial ovum, and to trace its progress from the ovary, where it is first formed, into the Marsupial pouch, where the development of the fœtus is ultimately completed.

(2440.) The ovary of a Marsupial animal, as has been already observed, resembles that of ordinary Mammalia, and presents the same dense structure. But the ovarian ovules, although characterized by the paucity of yelk as compared with the oviparous classes, yet have a larger proportion than exists in the placental Mammalia. When impregnation is effected in the Marsupial animal, the *Graafian vesicle* or *ovisac* is ruptured, and the little ovulum escapes into the Fallopian tube, whereby it passes into the uterine cavity, from whence, of course, it must absorb the materials destined to support the future embryo, in the same manner as the egg is furnished in the oviduct with the albumen that invests the yelk. The development of the embryo from the blastoderm or germinal membrane is, no doubt, accomplished in the same manner in all Mammalia as it is in Birds, up to a certain stage of maturity: but at that stage of growth when, in the case of the Bird, the yelk is required to contribute to the nourishment of the newly-formed being, in the Mammifera, where no adequate supply of yelk exists, other means must be resorted to; and accordingly the Marsupial embryo is born prematurely, in order to supply it with milk; and in the ordinary Mammal a placenta is developed, forming a means of vascular communication between the mother and the fœtus.

(2441.) The important investigations of Professor Owen upon this subject* cannot be too highly appreciated. In the gravid uterus of a Kangaroo, examined by this indefatigable labourer in the cause of science, a fœtus was met with that had apparently arrived very nearly at the term of its intra-uterine existence; and the following is a summary of its anatomy at this period.

(2442.) The ovum (fig. 416, *c*) was lodged in one of the uterine cavities, and the fœtus was about an inch and four lines in length. The walls of the gravid uterus were obviously dilated, and its parietes varied in thickness from one to two lines, being in the unimpregnated state about half a line; but this increase was not in the muscular coat, but in the lining membrane, which was thrown into irregular folds and wrinkles. There was, however, not the slightest trace of any vascular connexion between the uterus and the ovum—neither placenta nor villi, nor any determination of vessels to a given point on either of the opposed surfaces of the chorion or uterus: on the contrary, the external membrane of the ovum (*chorion*) exhibited not the slightest trace of vascularity, even under the microscope, and seemed in every respect to resemble the *membrana putaminis* that lines the egg-shell.

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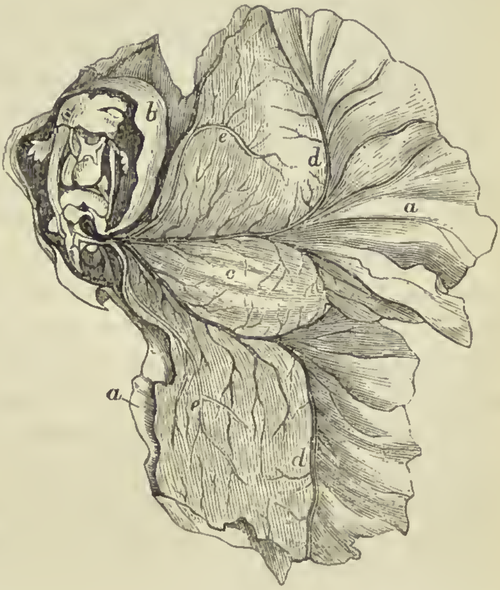
* "On the Generation of Marsupial Animals, with a Description of the Impregnated Uterus of the Kangaroo," by Richard Owen, Esq., Phil. Trans. 1834.

(2443.) The body of the fœtus itself was immediately enclosed in a transparent membrane (*b*), the *amnios.*

(2444.) Between the *chorion* (*a*) and the *amnios* (*b*) was an extensive vascular membrane (*c*, *d d*, *e e*): its figure seemed to have been that of a cone, of which the apex was at the umbilicus of the fœtus.

Fig. 417.



Embryo of Kangaroo.

(2445.) Three vessels could be distinguished diverging from the umbilical cord, and ramifying over it. Two of these trunks contained coagulated blood; while the third was smaller, empty, and evidently the arterial trunk. No trace of any other membrane could be seen extending from the fœtus, besides the three above mentioned—the chorion (*a*), the amnios (*b*), and the interposed vascular membrane, the nature of which becomes the next subject of inquiry.

(2446.) On tracing the three vessels above alluded to as ramifying over the vascular membrane through the umbilicus into the abdomen, the two larger ones, filled with coagulated blood, were found to unite, and, after being joined by the mesenteric vein, penetrated the liver: these, consequently, were the representatives of the *omphalo-mesenteric* or *vitelline* vein of the embryo Bird (§ 2136). The third vessel passed between the convolutions of the small intestine along the mesentery to the abdominal aorta, corresponding to an *omphalo-mesenteric* or *vitelline* artery. The membrane, therefore, upon which they ramified answers to the vascular layer of the germinal membrane which spreads over the yelk in the oviparous animals, or to the vitelline vesicle of the embryo of ordinary Mammalia.

(2447.) A filamentary pedicle connected this membrane to the intestine near the termination of the ilium, thus completing the resemblance between this apparatus and the vitelline system of Birds. But here we must caution the student not to be misled on one important point: the contents of the vitelline sac in the Marsupials, although doubtless intended to afford nourishment to the embryo animal, and thus representing the yelk of the Bird's egg, differ from it in one very essential circumstance. The yelk of the oviparous ovum is ready-formed in the ovary and exists prior to conception; but in the Mammal, where the ovarian yelk is met with in extremely small quantities, the contents of the vitellicle must obviously be derived from some other source, most probably from absorption from the uterine cavity.

(2448.) In the Marsupial ovum the vascular membrane of the vitellicle is doubtless sufficient for the respiration of the little creature up to the time of its birth; and accordingly the *allantoic system* (§ 2139) is but very partially developed. In the ovum delineated in the last figure, there was as yet no perceptible trace either of an *allantois* or of a urinary bladder; but, as has been proved by another dissection, during the latter weeks of uterine gestation the urinary bladder is prolonged beyond the umbilicus so as to form a small allantois destined to receive the renal secretion, which becomes more abundant as the little fœtus increases in size and completeness *.

(2449.) In the mammary fœtus of a Kangaroo a fortnight old, Professor Owen detected both a urachus and umbilical arteries; but these only extended from the bladder and iliac vessels as far as the umbilicus: neither could any umbilical vein be found penetrating the liver. It is in the placental Mammals that we shall find these vessels assuming their full importance, and developing themselves into a new system, whereby the communication between the mother and her offspring is still more effectually provided for.

(2450.) When we consider the very early period at which the young Kangaroo is born, namely, at about the thirty-ninth day after conception, it is only reasonable to suppose that the organs most immediately connected with the vital actions are precociously matured; and accordingly, even in the embryo above delineated (fig. 417), the intestines, the liver, the kidneys, and the testes were all conspicuous, and the diaphragm, the heart, and the lungs were in such an advanced condition as to show that they would soon be capable of prematurely taking upon themselves the exercise of the circulatory and respiratory functions.

(2451.) This rapid development of the viscera connected with circulation and respiration is, in truth, essentially requisite; for no sooner has the embryo arrived at the size represented in the next figure (fig. 418, A), the limbs being still in a most rudimentary condition, than the embryo is transferred from the uterus into the marsupial pouch, where it is found attached by its mouth to one of the nipples, from whence the materials of its support are to be obtained until it has acquired sufficient strength and size to leave the strange portable nest in which its fœtal growth is accomplished and procure food adapted to a maturer condition.

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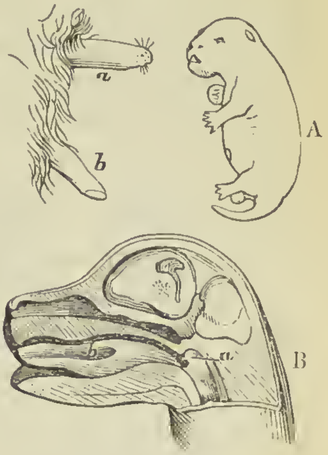
* See Proceedings of the Zoological Society for August 1837.

Fig. 418.



Fœtal Kangaroo.

(2452.) A very beautiful provision is met with in the construction of the respiratory passages of the young Marsupial, intended to obviate the possibility of suffocation consequent upon the admission of milk into the trachea—a circumstance that, without some peculiar arrangement, might easily happen; but of this we must quote the original description, extracted from the paper already referred to *. "The new-born Kangaroo," observes Professor Owen, "possesses greater powers of action than the same-sized embryo of a Sheep, and approximates more nearly in this respect to the new-born young of the Rat; yet it is evidently inferior to the latter. For although it is enabled by the muscular power of its lips to grasp and adhere firmly to the nipple, it seems to be unable to draw sustenance therefrom by its own unaided efforts. The mother, as Professor Geoffroy † and Mr. Morgan ‡ have shown, is therefore provided with a peculiar adaptation of a muscle (analogous to the cremaster) to the mammary gland, for the evident purpose of injecting the milk from the nipple into the mouth of the adherent fœtus. Now it can scarcely be supposed that the fœtal efforts of suction should always be coincident with the maternal act of injection; and if at any time this should not be the case, a fatal accident might happen from the milk being forcibly injected into the larynx. Professor Geoffroy first described the modification by which this purpose is effected; and Mr. Hunter appears to have foreseen the necessity for such a structure, for he has dissected two small fœtuses of the Kangaroo for the especial purpose of showing the relation of the larynx to the posterior nares §.

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* P.Z.S., August 1837, p. 348.

† Mémoires du Musée, tom. xxv. p. 48.

‡ Trans. Linn. Soc. vol. xvi. p. 61.

§ "See Nos. 3731, 3734, 3735, in the Physiological Series of the Hunterian Museum, in which there are evidences that Mr. Hunter had anticipated most of the anatomical discoveries which have subsequently been made upon the embryo of the Kangaroo."

The epiglottis and arytenoid cartilages are elongated and approximated, so that the rima glottidis is thus situated at the apex of a cone-shaped larynx (fig. 418, B, *a*), which projects, as in the CETACEA, into the posterior nares, where it is closely embraced by the muscles of the soft palate. The air-passage is thus completely separated from the fauces, and the injected milk passes in a divided stream, on either side of the larynx, into the œsophagus."

"Thus aided and protected by modifications of structure, both in the system of the mother and in its own, designed with especial reference to each other's peculiar condition, and affording therefore the most irrefragable evidence of Creative foresight, the feeble offspring continues to increase from sustenance exclusively derived from the mother for a period of about eight months. The young Kangaroo may then be seen frequently to protrude its head from the mouth of the pouch, and to crop the grass at the same time that the mother is browsing. Having thus acquired additional strength, it quits the pouch, and hops at first with a feeble and vacillating gait; but continues to return to the pouch for occasional shelter and supplies of food, till it has attained the weight of ten pounds. After this it will occasionally insert its head for the purpose of sucking, notwithstanding another fœtus may have been deposited in the pouch; for the latter, as we have seen, attaches itself to a different nipple from the one which had previously been in use."

(2453.) Thus therefore are we conducted by the *Ovovivipara*, as the MARSUPIALIA are properly called, to the most perfect or placental type of the generative system.

(2454.) Commencing our account of the reproductive organs of VIVIPAROUS MAMMALIA by examining those of the male sex, we have another striking example of the insufficiency of the nomenclature employed by the anatomist who confines his studies to the human body, when it becomes necessary to describe corresponding organs even in animals organized after the same type.

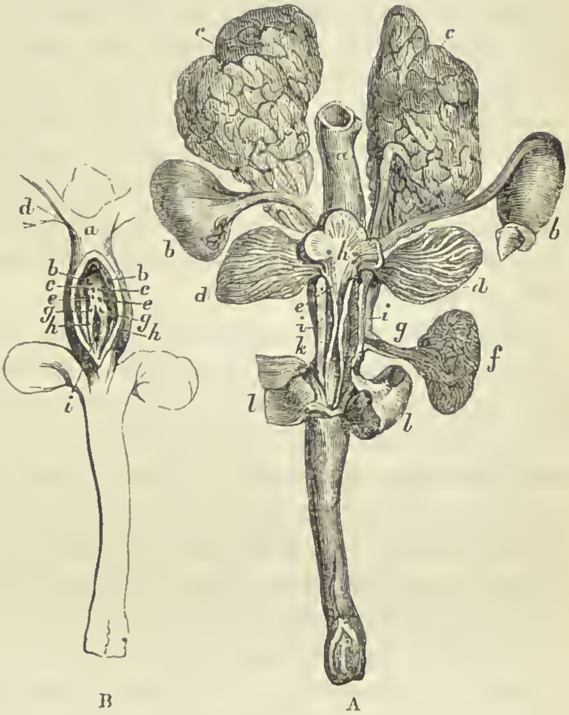
(2455.) True it is that there is the same general arrangement of the generative apparatus; and it is convenient, as far as possible, to apply the same names to structures that apparently represent each other: but a very superficial examination of the facts will serve to show that great differences exist between them; and, accordingly, we are not surprised to find the utmost perplexity and confusion in the descriptions of these parts, arising from the indiscriminate application of the terms employed in human anatomy to totally dissimilar structures.

(2456.) It is not, however, our business here to criticize the labours of authors upon this subject; we must content ourselves with selecting an example of one of the more complex forms under which the male genitals present themselves, and leave the reader to contrast the various organs with those met with in the human subject.

(2457.) The annexed figure (fig. 419, A) represents the generative viscera of the male Hedgehog. The *rectum* (*a*) and the neck of the bladder (*h*) remain *in situ*; but the rest of the latter viscus has been removed, and the first portion of the urethra (*e*) slit open, in order to show the relations of the surrounding parts.

(2458.) The *testes* (*b b*) present the same structure in all the class, and consist essentially of an immense assemblage of extremely delicate *tubuli seminiferi* enclosed in a dense albugineous tunic, from which septa pass internally, whereby the seminiferous tubes are divided into several fasciculi: after piercing the proper fibrous tunic of the testes, the sperm-secreting tubes are collected into an extremely tortuous duct, that by its convolutions forms the epididymis, as in Man, and is then continued, under the name of *vas deferens*, to the commencement of the urethra, into which the two ducts open (B, *b b*). In the Horse, and many Ruminants, the vas deferens presents a remarkable structure: before its termination it suddenly swells to a considerable diameter, depending upon the increased thickness of the walls of the canal, which at the same time become cellular, and secrete a gelatinous fluid that escapes into the cavity of the duct.

Fig. 419.



Male generative apparatus of the Hedgehog.

(2459.) In their situation the testes of placental Mammals are found to offer very striking differences. In the Cetacea, the Elephant, and the Seal, they remain permanently in the abdomen, bound down by a process of the peritoneum. In Man, and most quadrupeds, on the contrary, they pass out of the abdominal cavity through the inguinal rings, and are suspended in a scrotal pouch formed by the skin, and a cremaster muscle, and lined by a serous prolongation of the peritoneal sac. The spermatic cords, therefore, formed by the vessels and excretory canal of the testes, will take a different course, in conformity with the variable position of these organs, and, where a scrotum exists, must enter the abdomen through an inguinal canal. Still, from their horizontal posture, quadrupeds are but little liable to hernia, even where the inguinal passages are much more open than in the human subject.

(2460.) The quantity of the seminal fluid furnished by the testes is very small, as must be evident from the extreme narrowness of the duct through which it passes into the urethra. Nevertheless, as the impregnation of the female now requires the forcible injection of this fluid, it is absolutely requisite to increase the bulk of the vivifying secretion, in order to enable the muscles that embrace the urethral tube efficiently to expel it. For this purpose additional glands are given, whereby different fluids are poured into the urethral cavity, apparently for the sole purpose of diluting the spermatic liquor, and thus forming a vehicle for its expulsion. These *succenturiate glands,* as they are named, are not found in any oviparous animal; but in the Mammal such is their size and importance that there may be just reason for supposing them to exercise a more important office than that usually assigned to them by physiologists; and this supposition seems to obtain additional weight when we consider the great diversity of structure that they exhibit in different quadrupeds.

(2461.) The *vesiculæ seminales* are the first of these accessory secreting organs that require our notice. In Man, the seminal vesicles, as they are erroneously termed, resemble two membranous reservoirs, situated beneath the neck of the bladder, and were once supposed to be receptacles for containing the semen. When opened, however, they are found to be composed of the windings of a very sinuous secreting surface; and as their excretory ducts open into the urethra in common with the vasa deferentia, they obviously add the fluid that they elaborate to the secretion of the testes.

(2462.) But notwithstanding their apparent importance in the human species, these organs do not exist at all in by far the greater number of Carnivora; neither are they found in the Ruminants, nor in the cetaceous Mammals.

(2463.) In other quadrupeds, on the contrary, they are found, and their proportionate size is extremely remarkable. This is specially the case in the Rodent tribes and among the Insectivora. In the Hedgehog, for example, their bulk is enormous. In this creature they form two large masses (fig. 419, A, *c c*), each composed of four or five bundles of long and tortuous secerning vessels folded upon themselves in all directions, and pouring the product of their secretion into the urethra by two ducts (fig. 419, B, *c c*), quite distinct from the *vasa deferentia.*

(2464.) The *prostates* are the next succenturiate glands, superadded to the essential generative organs of the placental Mammals; and so diverse is their structure in different tribes, that it is not always easy to recognize them under the varied forms that they assume.

(2465.) In Man the *prostate* is a solid glandular mass, that embraces the commencement of the urethra, into which it discharges its secretion by numerous small ducts; and this is the most common arrangement throughout the Mammiferous orders.

(2466.) In Ruminants, Solipeds, and in the Elephant, there are two or even four prostates, of a very different kind, each gland having a central cavity, into which smaller cavities open by wide orifices. In these creatures, therefore, the prostatic secretion accumulates in the interior of the gland, from whence it is conveyed into the urethra by appropriate excretory canals.

(2467.) In most of the Rodentia, in the Mole, and in the Hedgehog, the structure of the prostate is so peculiar that many distinguished comparative anatomists refuse to apply the same name to organs that obviously represent the gland we are describing, preferring, with Cuvier, to call them "*accessory vesicles.*"

(2468.) In the Hedgehog, the prostate is replaced by two large masses (fig. 419, A, *d d*), each composed of parallel, flexuous, and branched tubes, all of which unite into ducts common to the whole group, whereby the fluid elaborated is conveyed into the urethra through minute orifices (fig. 419, B, *e e*).

(2469.) A third sot of auxiliary secreting bodies, very generally met with, are called by the name of "*Cowper's glands.*" These in our own species are very small, not exceeding the size of a pea; but in many quadrupeds they are much more largely developed. In the Hedgehog (fig. 419, A, *f*) they are obviously composed of convoluted tubes, and their ducts open by distinct apertures (B, *g g*) into the floor of the urethra.

(2470.) The canal of the urethra, through which the urine as well as the generative secretions are expelled from the body of the male Mammal, is a complete tube, and no longer a mere furrow, as we have seen it to be in all the Ovipara possessed of an intromittent apparatus. It extends from the neck of the bladder to the extremity of the penis; but in this course, owing to its relations with the surrounding parts, it will be necessary to consider it as divisible into two or three distinct portions, each of which offers peculiarities worthy of remark. The first part of the urethral tube is not unfrequently, as in the human subject, more or less completely surrounded by the prostate gland, and in such cases merits the name of "*prostatic portion;*" but where, as in the Hedgehog, the prostates do not enclose the commencement of the canal, this division of the urethra does not exist.

(2471.) The second is the "muscular portion," extending from the prostate to the root of the penis; and it is into this part that all the generative secretions are poured from their respective ducts (fig. 419, B, *b*, *c*, *e*, *g*, *h*). Externally this division of the urethra is enclosed by strong muscles (fig. 419, A, *i i*), which by their convulsive contractions forcibly ejaculate the different fluids concerned in impregnation, and thus secure an efficient intromission of the seminal liquor into the female organs.

(2472.) The third portion of the urethra is enclosed in the body of the penis, and surrounded by the erectile tissue, of which that organ essentially consists; but in all quadrupeds this part of the canal is not so decidedly continuous with the muscular portion as it appears to be in Man and the generality of Mammalia. In many Ruminants, and in some of the Hog tribe, the muscular division of the canal opens into the upper part of the third or vascular division, in such a manner that a *cul de sac* occupies the commencement of the vascular *bulb of the urethra*, as it is called by anatomists, into which the secretion of Cowper's glands is poured without having been previously mixed with the seminal or prostatic fluids. In some Rodents, as, for example, in the Squirrel and the Marmot, the arrangement is still more curious; for the *cul de sac* of the bulb of the urethra in these creatures, which receives the secretion of Cowper's glands, is lengthened out into a long tube that runs for some distance beneath the proper urethra, and only joins that canal near the extremity of the penis.

(2473.) The body of the penis in the Mammalia, as in all other Vertebrata possessed of such an organ, is composed of vascular erectile tissue; but now, besides the *corpora cavernosa*, which in Reptiles and Birds formed the entire organ, another portion is superadded, destined to enclose the canal of the urethra in a thick erectile sheath, and, moreover, to form the *glans*, or most sensitive part of the intromittent apparatus.

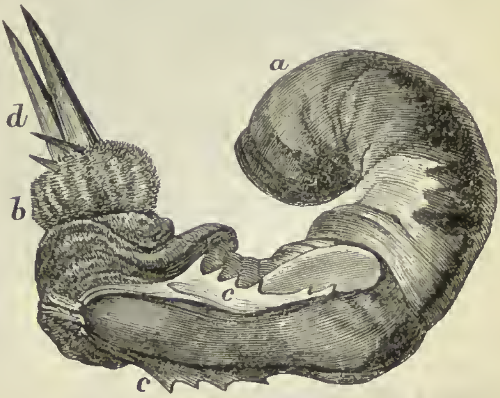
(2474.) The *corpora cavernosa* are now securely fixed to the bones of the pelvis by two roots or *crura*; and even in the Cetacea, where no pelvis is met with, the *ossa ischii* exist, apparently, only for the purpose of giving firm support to the origin of the parts in question. The size of the *corpora cavernosa* in Man, and many other animals, is of itself sufficient to give the needful rigidity to the parts during sexual excitement; but in some tribes an additional provision is required to ensure adequate firmness. Thus in Monkeys, Bats, the Carnivora, the Rodentia, and the *Balænidæ* among Cetaceans, a bone is imbedded in the substance of the male organ, of which it forms a considerable part. Where this bone exists, the *corpora cavernosa* are proportionately small, and the fibrous walls of the penis are confounded with its periosteal covering.

(2475.) The *corpus spongiosum*, likewise composed of erectile tissue, is quite distinct from the cavernous bodies, and, as we have said before, is only found in the Mammifera. It commences by a bulbous origin that embraces the urethra, and it accompanies that canal quite to the extremity of the penis, where it dilates into the glans.

(2476.) The size and shape of the male organ varies, of course, in every genus of quadrupeds, as does the form and texture of the glans. To describe these would lead us into details of too little importance to be noticed in a survey so general as that we are now taking; nevertheless we cannot entirely omit to notice the strange and unaccountable structure met with in some of the Rodent tribes, whereby the penis is rendered a most formidable-looking apparatus, the object of which it is not easy to conjecture, although, as an instrument of excitement, no one will be disposed to deny its efficiency.

(2477.) Thus, in the Guinea-pig tribe (*Cavia*, Illig.), the penis is strengthened by a flat bone that reaches forward as far as the extremity of the gland beneath which is the termination of the urethra; but behind and below the orifice of this canal is the opening of a pouch, wherein are lodged two long horny spikes. When the member is erect, the pouch alluded to becomes everted, and the spikes (fig. 420, *d*) are protruded externally to a considerable length. Both the erected pouch (*b*) and the entire surface of the glans are, moreover, covered densely with sharp spines or hooklets; and as though even all this were not sufficient to produce the needful irritation, still further back there are, in some species, two sharp and strong horny saws (*c c*) appended to the sides of the organ. From this terrible armature of the male Cavies, it would be only natural to expect some corresponding peculiarity in the female parts; but, however inexplicable it may appear, the female vagina offers no uncommon structure.

Fig. 420.



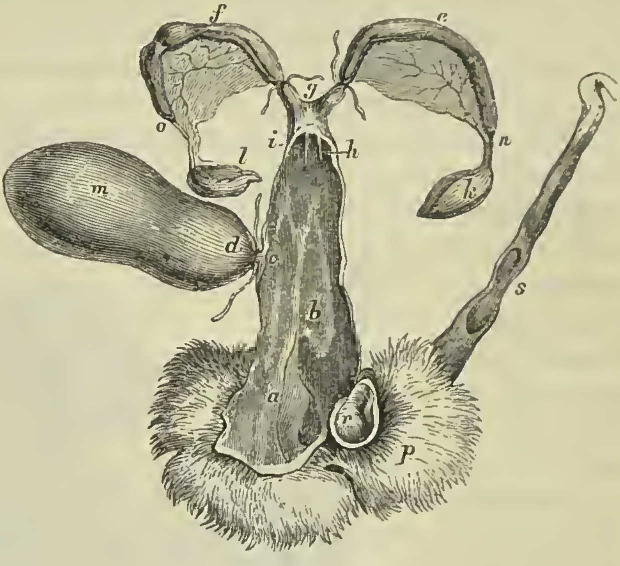
Penis of the Agouti.

(2478.) We have, in the last place, to examine the generative system of the female placental Mammalia, and thus to trace the development of this important system to its most complete and highest form.

(2479.) In the Marsupialia, as the reader will remember, there were still two distinct uteri, that were obviously the representatives of the oviducts of the Oviparous classes. In the Human female, on the contrary, the uterus is a single central viscus, into which the germs derived from the ovaria are introduced through the two "*Fallopian tubes,*" as the oviducts are now designated; but we shall soon see that the viviparous Mammals offer in the anatomical structure of the generative system of the female so many intermediate gradations of form, that we are almost insensibly conducted even from the divided uteri of the Ornithorhynchus up to the most elevated and concentrated condition that the uterine apparatus ultimately attains in our own species.

(2480.) In the female Rabbit, for example, we have a placental Mammal that in every part of the organization of its reproductive organs testifies its near affinity to the Marsupial type. The ovaria (fig. 421, *k*, *l*), although widely different as regards the size of the contained ovules from those of oviparous animals, still retain faint traces of a botryoidal or racemose appearance.

Fig. 421.

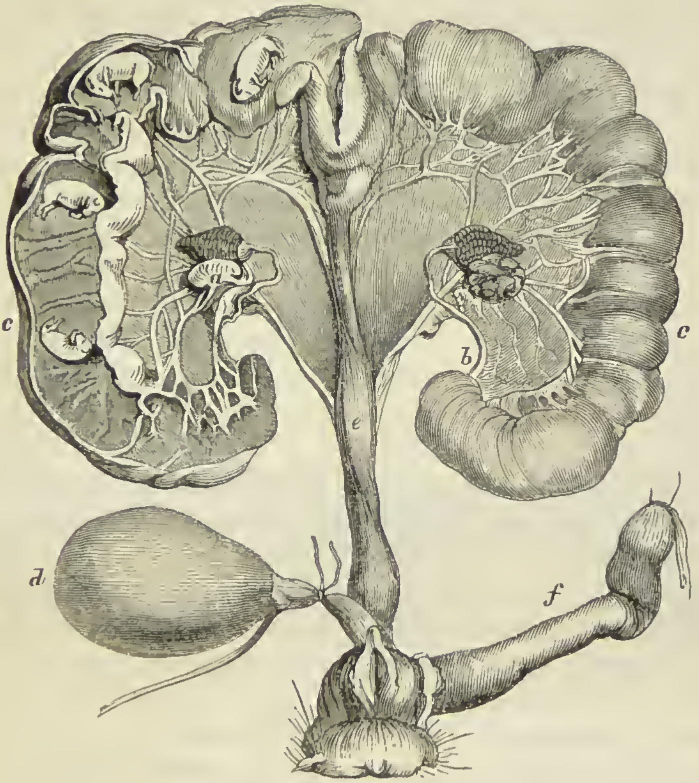


Uterus of the Rabbit.

(2481.) The *oviducts* (*n*, *o*), or the *Fallopian tubes* as we must now call them, are reduced in their diameter to very small dimensions, and testify by their tenuity how minute must be the ovule to which they give passage. To these succeed the *uteri* (*e*, *f*), still entirely distinct from each other throughout their whole extent, and even opening into the vagina (*g*) by separate orifices, into which the probes (*i*, *h*) have been introduced. As far as its anatomy is concerned, such a uterine apparatus might belong to a marsupial Mammifer; and even in the rest of the sexual parts, obvious relations may be traced between the rodent we are describing and the ovoviviparous quadrupeds.

(2482.) It is true there are no longer two vaginæ terminating in a single cloacal cavity; but let the reader observe how nearly the vagina of the Rabbit (fig. 421, *a*, *b*) approximates the condition of a cloacal chamber. Anteriorly it receives the contents of the bladder (*d*, *m*); while the rectum (*s*) terminates by an anal orifice (*r*) so closely conjoined with the aperture of the vulva, that the anatomist is almost in doubt whether the external opening might not be described as common both to the vagina and intestine. Advancing from this lowest form of a placental uterine system, it is found that the two uteri before their termination become united so as to form a central portion common to both, called the body of the uterus, through the intervention of which they communicate with the vagina by a single passage, named the *os tincæ*; still, however, the *cornua uteri*, especially in those tribes that are most remarkable for their fecundity, become during gestation far more capacious than the mesial portion of which they appear to be prolongations. It is, in fact, in the cornua that the numerous progeny of such animals are lodged during the whole time of their retention in the uterus; and consequently such an arrangement is absolutely requisite, as must be evident from simply inspecting the gravid uterus of a Sow (fig. 422), where the *cornua uteri* (*c c*) are of remarkable dimensions.

Fig. 422.



Uterus of the Sow.

(2483.) As we ascend from the more prolific inferior races to the Quadrumana and the Human species, the proportionate size of the body of the uterus becomes materially increased, and that of the cornua diminishes in the same ratio, until in the Monkeys and in Woman the latter become quite lost, and the now pyriform central part appears to compose the entire viscus, into the cavity of which the Fallopian tubes seem immediately to discharge themselves. Thus gradually, therefore, does the oviparous sexual apparatus assume the viviparous type; and then, passing through numerous intermediate forms, ultimately attains its most concentrated condition in the uterus of the Human female.

(2484.) In every other part of the generative system we shall likewise find the characters of the type at length completely established.

The *ovaria* (fig. 422, *a*) entirely lose all traces of their original racemose condition; for now the quantity of granular matter enclosed along with the germ in each Graafian vesicle, the last remnant of the yelk, has become almost inappreciable, and the little ovarian ovules are enclosed in a dense parenchymatous substance enveloped by a smooth albugineous tunic. The Fallopian tubes (*b*) correspond, in the smallness of their diameter, with the minuteness of the globules they are destined to convey from the ovaries into the uterine receptacle; and lastly, the excretory canal of the bladder (*d*) becomes quite separated from the vagina (*e*), and the anal and generative apertures are found completely distinct from each other.

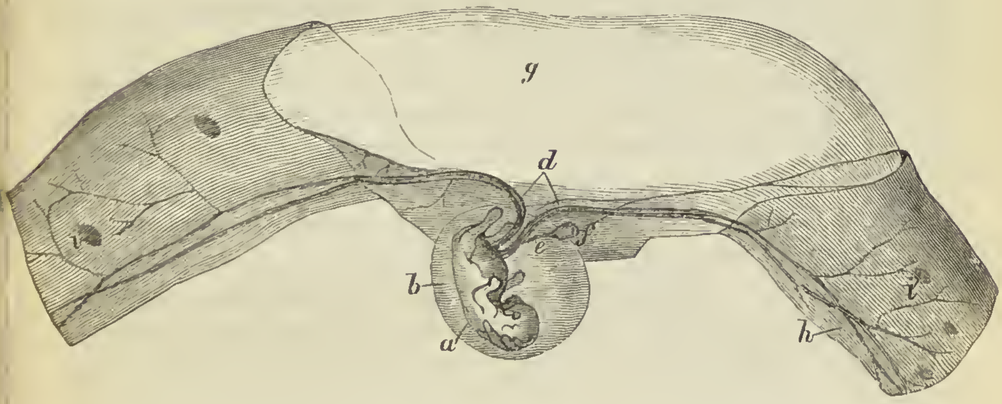
(2485.) After the above brief sketch of the anatomy of the organs of generation in the higher Mammalia, it now remains for us to trace the development of the germ from the moment of impregnation to the birth of the fœtus, and observe in what particulars placental generation differs from the oviparous and ovoviviparous types already described. In the *viviparous* or placental Mammifer the effect of impregnation is the bursting of one or more of the *Graafian vesicles*, and the escape of the contained germs from the ovisacs wherein they were formed. In the Ovipara, owing to the delicacy of the ovisacs, the vascular membranes composing them, when once ruptured, are speedily removed by absorption; but in the Mammal this is not the case, and a cicatrix remains permanently visible upon the surface of the ovary, indicating where the rupture has occurred: such cicatrices are known by the name of *corpora lutea*.

(2486.) On the rupture of the ovarian ovisac, the *vesicle of Purkinje*, or the essential germ, accompanied only by a most minute quantity of granular fluid, or yelk, is taken up by the fimbriated extremity of the Fallopian tube, and conveyed into the interior of the uterus, where its development commences. Observations are wanting to teach us precisely what are the first appearances of the embryo; but there is not the least doubt that the materials for its earliest growth are absorbed in the cavity of the womb, and that its formation from a *blastoderm*, or germinal membrane, is exactly comparable to what occurs in the egg of the Bird, already minutely described in the last chapter (§ 2110 *et seq.*), and that, in every particular, as relates to the growth and functions of the *vitelline* or *omphalo-mesenteric* as well as of the *amniotic* systems, the phenomena are the same as in the marsupial Mammal up to the period when the young Marsupian is prematurely born, to be afterwards nourished in the pouch of its mother from materials derived from the breast.

(2487.) But precisely at that point of development where the Marsupial embryo is expelled from the uterus of its parent, namely, when the functions both of the vitellicle and of the allantoid apparatus become no longer efficient either for nutrition or respiration, a third system of organs is developed in the placental Mammifer, whereby a vascular intercommunication is established between the fœtus and the uterine vessels of the mother, forming what has been named by human embryologists the *placenta*.

(2488.) In the ovum of a Sheep, at that period of the growth of the fœtus which nearly corresponds with the end of uterogestation in the prematurely-born Kangaroo, all the three systems alluded to are coexistent and easily distinguishable, as will be seen in the accompanying figure (fig. 423). The fœtus (*a*), enclosed in its *amniotic membrane* (*b*), has its limbs as yet but very imperfectly formed, exhibiting pretty nearly the condition of a nascent Marsupial (*vide* fig. 418); but here it will be seen that the umbilical systems exhibit very striking differences in the two races. The *vitellicle* (*f*), with its pedicle (*e*), are of very small dimensions; the *allantoid sac* (*g*), on the contrary, is of considerable bulk, and, having ceased to act as a respiratory organ, becomes adapted to receive the urinary secretion through the canal of the *urachus*. The most important feature, however, is the rapid extension of the umbilical vessels (*d*), which in Birds and Marsupials were distributed only to the *allantois*, but in the placental Mammals these vessels rapidly spread over the *chorion* (*h*), and, coming in contact with the vascular surface of the womb, they soon form a new bond of communication between the mother and the fœtus, constituting the placenta; and thus the offspring is nourished until, its intra-uterine growth being accomplished, it is born in an advanced condition of development, and becomes the object of maternal care during that period in which it is dependent upon the breast of its mother for support.

Fig. 423.



Embryo of the Sheep.

(2489.) The appearance of the *placenta* varies much in different tribes: thus in the Sheep and other Ruminants it consists of numerous detached masses of villi (fig. 423, *i i*), that interdigitate with corresponding processes derived from the maternal womb; in the Mare it covers the whole surface of the chorion: but in the greater number of Mammals, and in the Human female, it forms a single vascular *cake*, whence is derived the name appropriated by anatomists to this important viscus.

(2490.) After the development of the placental system, it is obvious that the arteries derived from the common iliac trunks of the fœtus, which at first were distributed only to the *allantois*, as in the case of the Bird (§ 2139), on the development of the *placenta* become transferred to the latter viscus, and form the *umbilical arteries* of the navel-string. The vein, likewise, notwithstanding its prodigiously-increased extent of origin after the placenta has been formed, takes the same course on entering the umbilicus of the fœtus as it did when it was derived only from the *allantois*; so that, although the placenta completely usurps the place of the allantois, both the allantoic and placental circulations are carried on through the same umbilical arteries and veins.

(2491.) In order to complete our history of fœtal development up to the full establishment of the permanent double circulation that characterizes all the hot-blooded Vertebrata after birth, it only remains for us to notice the changes that occur in the vessels of the fœtus, whereby, on the cessation of the functions of the placenta, the pulmonary circulation is at length brought into action.

(2492.) Up to the period of birth the arrangement of the fœtal circulation remains essentially that of a Reptile, inasmuch as both the venous blood derived from the system and the arterialized blood that comes from the placenta are mixed together in the as yet imperfectly separated chambers of the heart. Under these circumstances the arrangement of the vascular system is as follows:—Pure blood, supplied from the placenta, is brought into the body by the umbilical vein, which passes partly into the portal system of the liver, but principally through the *ductus venosus* into the *inferior cava*, and thence into the heart. From the construction of the heart during this portion of fœtal existence it is obvious that in that viscus all the blood derived from the placenta, from the venous system of the fœtus, and also from the as yet inactive lungs, is mingled together prior to its distribution through the arterial system. The two auricles communicate freely with each other through the *foramen ovale*; and, by means of the *ductus arteriosus*, the greater portion of the blood driven from the right ventricle during the systole of that cavity passes into the aorta, a very small proportion only finding its way into the pulmonary arteries. Such a heart, therefore, supplies to the fœtal system a mixed fluid, of which a portion, having passed through the arterial trunks, finds its way back to the placenta through the two umbilical arteries, there to recommence the same circle.

(2493.) Immediately after birth, however, the whole arrangement is altered, and the adult condition fully established. The lungs assume their functions and the pulmonary arteries attain their full proportions, while the placenta at once ceases from its office, and all the umbilical vessels become obliterated. The *ductus venosus* is no longer permeable, so that the *portal system* and that of the *venæ cavæ* are quite separated: the *foramen ovale* closes, thus completely separating the right from the left auricle: the *ductus arteriosus* is reduced to a mere ligament; all the blood, therefore, driven from the right side of the heart must now pass into the expanded lungs, and be returned through the pulmonary veins to the left side of the heart. Thus the pulmonary and systemic circulations being rendered totally distinct, arterialized blood alone enters the arterial system, to be distributed through the body, and, the umbilical arteries disappearing, the highest form of the circulatory apparatus is fully established.

(2494.) After birth the *mammary glands* supply the first nutriment to the still helpless offspring. These vary in number and position in different species of placental Mammifers, their number being of course greatest in the most prolific races. Where the arms or anterior limbs can be used for supporting or clasping the feeble young, as in the Quadrumana, the Bats, and the females of our own species, it is upon the breast that these nutrient founts are placed; but in less gifted tribes the *mammæ* are situated beneath the abdomen or in the inguinal region. Their structure, however, is similar throughout the entire class; each gland consisting of innumerable minute secreting cells, grouped together in lobules and in lobes. Delicate excretory ducts, derived from all these ultimate cells, unite together again and again until they form capacious ducts, or rather reservoirs for milk. In the Human female the lactiferous canals terminate by numerous orifices upon the extremity of the nipple; but where the nipples are of large size, they generally contain a wide cavity wherein the milk accumulates in considerable quantities, to be discharged through one or two orifices only. Such are the modes by which Supreme Beneficence has provided for the infant progeny of Mammiferous beings, and conferred the endearments of maternity where He has bestowed intelligence to appreciate affection. But even this is not all: from the superabundance of the store provided there may be yet to spare; and Man is privileged to bid his lowing herds yield him their milk for food, and thus obtains no slight addition to the bounteous table spread for his enjoyment.

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